



NCERT NOTES

GEOGRAPHY

11th Standard

Fundamentals of
Physical Geography

Content Sheet

Unit I: Geography as a Discipline	3
1. Geography as a Discipline	4
Unit II: The Earth	8
2. The Origin and the Evolution of the Earth	9
3. Interior of the Earth	16
4. Distribution of Oceans and Continents	24
Unit III: Landforms	33
5. Minerals and Rocks	34
6. Geomorphic Processes	38
7. Landforms and their Evolution	48
Unit IV: Climate	61
8. Composition and Structure of the Atmosphere	62
9. Solar Radiation, Heat Balance and Temperature	65
10. Atmospheric Circulation and Weather Systems	72
11. Water in the Atmosphere	83
12. World Climate and Climate Change	88
Unit V: Water (Oceans)	96
13. Water (Oceans)	97
14. Movements of Ocean Water	104
Unit VI: Life on the Earth	111
15. Life on the Earth	112
16. Biodiversity and Conservation	120



Unit I: Geography as a Discipline

Geography is described as **description of the earth**. Geography as an independent subject helps us to learn about the **physical environment** of the Earth, **human activities**, and their **interactive relationships**. It derives its data base from all the natural and social sciences and attempts their synthesis.

Geography as a discipline is concerned with three sets of questions:

- **Distributional and Locational aspect:**
 - Some questions are related to the identification of the patterns of **natural and cultural features** as found over the surface of the earth. These are the **questions about what?**
 - Some questions are related to the **distribution** of the natural and human/ cultural features over the surface of the earth. These are the **questions about where?**
- **Scientific discipline:**
 - It is related to the explanation or the **causal relationships** between features and the processes and phenomena. This aspect of geography is related to the **question, why?**

Geography as an Integrating Discipline:

- Geography is a discipline of synthesis and **attempts spatial synthesis**.
- Its approach is holistic in nature and recognises the fact that the **world is a system of interdependencies**.
- Geography as an integrating discipline has **interface with numerous natural and social sciences**.

- It attempts to **comprehend the associations of phenomena** as related in sections of reality.
- All the branches of physical geography have interface with natural sciences.
- All the social science disciplines, viz. sociology, political science, economics, and demography study different aspects of social reality.
- The branches of geography, viz. social, political, economic and population and settlements are closely linked with these disciplines as each one of them has spatial attributes.

Major approaches to study Geography:

- **Systematic Geography approach:**
 - It was introduced by **Alexander Von Humboldt**, a German geographer (1769-1859).
 - The phenomenon is studied world over as a whole, and then the identification of typologies or spatial patterns is done.
- **Regional Geography approach:**
 - It was developed by another German geographer **Karl Ritter** (1779-1859).
 - The world is divided into regions at different hierarchical levels and then all the geographical phenomena in a particular region are studied.

Branches of the Geography (Based on Schematic Approach)

Physical Geography:

- **Geomorphology:** It is devoted to the study of **landforms**, their evolution, and related processes.

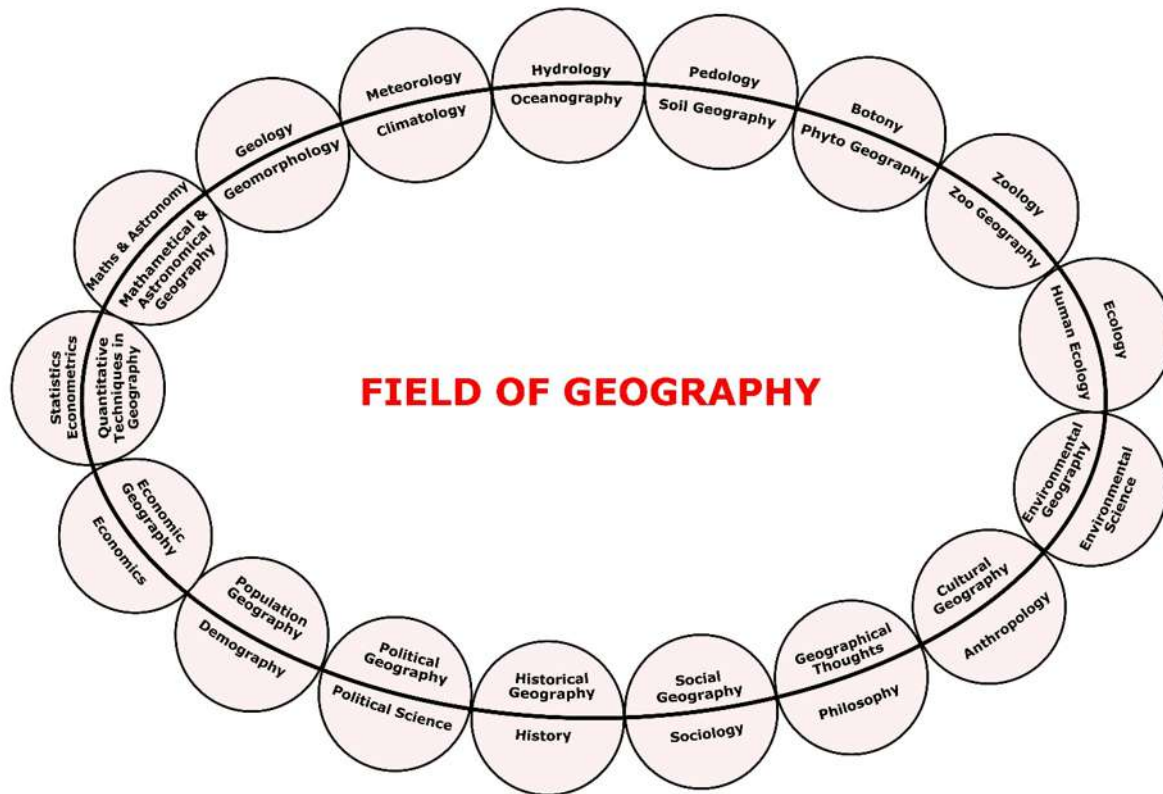


Fig. 1.1: Geography and its relations with other disciplines

- **Climatology:** It encompasses the study of **structure of atmosphere** and elements of weather and climates and climatic types and regions.
- **Hydrology:** It studies the realm of **water over the surface** of the earth including oceans, lakes, rivers and other water bodies and its effect on different life forms including human life and their activities.
- **Soil Geography:** It is devoted to study the processes of **soil formation**, soil types, their fertility status, distribution, and use.
- **Human Geography:**
 - **Social/Cultural Geography:** It encompasses the **study of society** and its spatial dynamics as well as the **cultural elements** contributed by the society.
 - **Population and Settlement Geography (Rural and Urban):** It studies **population** growth, distribution, density, sex ratio, migration, and occupational structure etc. Settlement geography studies the characteristics of rural and urban settlements.
 - **Economic Geography:** It studies **economic activities** of the people

including agriculture, industry, tourism, trade, transport, infrastructure, and services, etc.

- **Historical Geography:** It studies the **historical processes** through which the space gets organised. Every region has undergone some historical experiences before attaining the present-day status. The geographical features also experience temporal changes, and

these form the concerns of historical geography.

- **Political Geography:** It looks at the space from the angle of **political events** and studies boundaries, space relations between neighbouring political units, delimitation of constituencies, election scenario and develops theoretical framework to understand the political behaviour of the population.

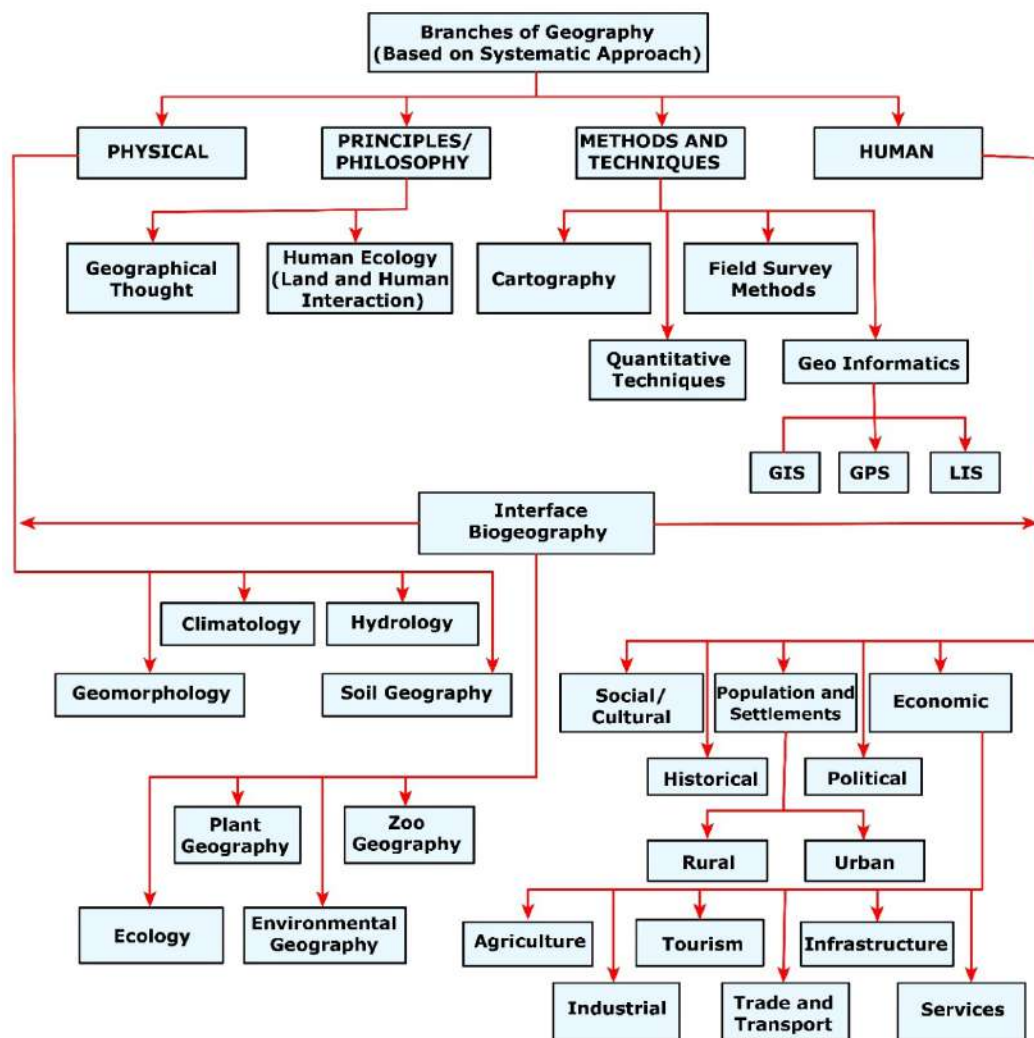


Fig. 1.2: Branches of geography based on Systematic Approach

Biogeography: The **interface** between **physical geography** and **human geography** has led to the development of Biogeography which includes:

- **Plant Geography:** It studies the spatial pattern of **natural vegetation** in their habitats.
- **Zoo Geography:** It studies the spatial patterns and geographic characteristics of **animals and their habitats**.
- **Ecology /Ecosystem:** It deals with the scientific study of the **habitat's characteristic of species**.
- **Environmental Geography:** It concerns world over leading to the realisation of **environmental problems** such as

land gradation, pollution and concerns for conservation, has resulted in the introduction of this new branch in geography.

Interesting Points:

- The **term geography** was first coined by **Eratosthenese**, a Greek scholar (276-194 BC.). The word has been derived from two roots from Greek language **geo** (earth) and **graphos** (description). Put together, they mean description of the earth.
- **Soils** are formed through the process known as **pedogenesis**.



Unit II: The Earth



The world which is present today has not been same from time immemorial. It has continuously changed as a result of evolution of the earth.

Early Theories of Evolution

Origin of The Earth: A large number of hypothesis were put forth by different philosophers and scientists regarding the origin of the earth.

- One of the earlier and popular arguments was **given by German philosopher Immanuel Kant** which was **revised by the mathematician Laplace** in 1796. It is known as **Nebular Hypothesis**.
 - The hypothesis considered that the **planets were formed out of a cloud** of material associated with a youthful sun, which was slowly rotating.
- In 1900, **Chamberlain and Moulton** considered that a wandering star approached the sun. As a result, a **cigar-shaped extension of material was separated from the solar surface**.
 - As the passing star moved away, the material separated from the solar surface continued to revolve around the sun and it slowly condensed into planets.
 - **Sir James Jeans** and later **Sir Harold Jeffrey** supported this argument.
- **Binary theories:** The arguments considered of a **companion to the sun to have been coexisting**.
- In 1950, **Otto Schmidt** and **Carl Weizascar** revised the 'nebular hypothesis' and considered that:

- The **sun was surrounded by solar nebula** containing mostly the hydrogen and helium along with what may be termed as dust.
- The **friction and collision of particles** led to formation of a **disk-shaped cloud** and the planets were formed through the **process of accretion**.

Modern Theories of Evolution

Origin of the Universe:

The scientists in later period took up the problems of origin of universe rather than that of just the earth or the planets.

Big Bang Theory:

- It is most popular argument regarding the origin of the universe and is also called **expanding universe hypothesis**.
- **Edwin Hubble**, in 1920, provided evidence that the **universe is expanding**.
- The distance between the galaxies is found to be increasing and thereby, **the universe is considered to be expanding**.

Development of the Universe as per Big Bang Theory:

- **In the beginning:** All matter forming the universe existed in one place in the form of a **"tiny ball"** (singular atom) with an unimaginably small volume, infinite temperature, and infinite density.

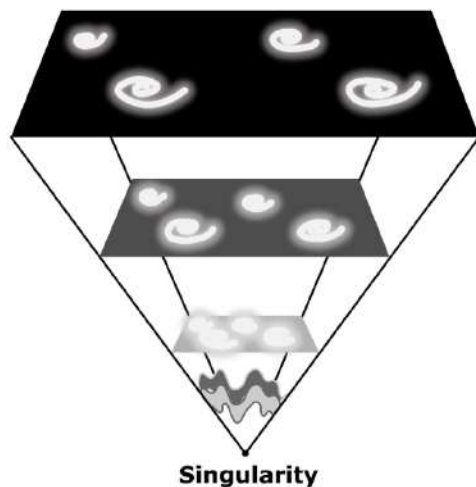


Fig. 2.1: The Big Bang

- **At the Big Bang:**
 - The “**tiny ball**” **exploded violently** which led to a **huge expansion**.
 - It is generally accepted that the event of big bang took place **13.7 billion years** before the present time.
 - The **expansion continues even to the present day** and as it grew, some energy was converted into matter.
 - There was particularly rapid expansion within fractions of a second after the bang. Thereafter, the expansion has slowed down.
 - Within **first three minutes** from the Big Bang event, **the first atom began to form**.

- **Within 300,000 years from the Big Bang:** The temperature dropped to 4,500 K (Kelvin) and gave rise to atomic matter. The **universe became transparent**.

Hoyle’s concept of steady state:

It considered the **universe to be roughly the same at any point of time**. However, with greater evidence becoming available about the expanding universe, scientific community at present favours argument of expanding universe.

Formation of Star:

- **Formation of Stars:** A galaxy starts to form **by accumulation of hydrogen gas** in the form of a very large cloud called **nebula**. Eventually, growing nebula develops localised clumps of gas which continue to grow into even denser gaseous bodies, **giving rise to formation of stars**. The formation of stars is believed to have taken place some **5-6 billion years ago**.
- **Basis of development of Galaxies:** The distribution of matter and energy was not even in the early universe which gave rise to **differences in gravitational forces**, and it caused the matter to get drawn together.

Galaxy: It contains a **large number of stars** and spread over vast distances that are **measured in thousands of light-years**. Its diameter ranges from 80,000-150,000 light years.

**Formation of Planets:**

- **First Stage:** The **gravitational force** within the gas lumps leads to the **formation of a core** to the gas cloud and a **huge rotating disc of gas and dust** develops around the gas core.
- **Second Stage:**
 - The gas cloud starts **getting condensed** and the matter around the core develops into small-rounded objects which further developed into **planetesimals** by cohesion.
 - **Larger bodies start forming by collision**, and gravitational attraction causes the material to stick together.

Planetesimals are a large number of smaller bodies.

- **Third Stage:** The **planetesimals accrete** to form a fewer large bodies in the form of planets.

The Solar System:

- It consists of the **Sun** (the star), **8 Planets**, **63 Moons**, millions of smaller bodies like **asteroids and comets** and huge quantity of **dust-grains and gases**.
- It is supposed to be **formed from the nebula** which started its collapse and core formation around **5-5.6 billion** years ago and the **planets were formed about 4.6 billion** years ago.

Table 2.1: The Solar System

	Mercury	Venus	Earth	Mars	Juptter	Saturn	Uranus	Neptune
Distance*	0.387	0.723	1.000	1.524	5.203	9.539	19.182	30.058
Density@	5.44	5.245	5.517	3.945	1.33	0.70	1.17	1.66
Radius#	0.383	0.949	1.000	0.533	11.19	9.460	4.11	3.88
Satellites	0	0	1	2	about 53	about 53	about 27	13

- **Types of Planets:**

Inner Planets	Outer Planets
They include Mercury, Venus, Earth, and Mars as they lie between the Sun and the belt of Asteroids .	They include other four planets, and all lie outside the belt of Asteroids .
They are Terrestrial (earth-like) as they are made up of rock and metals and have relatively high densities.	They are called Jovian (Jupiter-like) or gas giant planets .



Inner Planets	Outer Planets
They are smaller in size.	Most of them are much larger than the terrestrial planets and have thick atmosphere, mostly of helium and hydrogen.

Reasons for the Differences in Terrestrial and Jovian Planets:

- **Location:** The **terrestrial planets** were formed in the **close vicinity** of the parent star where it was too warm for gases to condense to solid particles. **Jovian planets were formed at quite a distant location.**
- **Solar Winds:** It was most **intense nearer the sun**. So, it **blew off lots of gas and dust from the terrestrial planets** whereas it was not that intense to cause similar removal of gases from the Jovian planets.
- **Size:** The **terrestrial planets are smaller**, and their lower gravity could not hold the escaping gases.

The Moon: The moon is the **only natural satellite of the earth**.

Theories Related to Origin of the Moon:

- In 1838, **Sir George Darwin** suggested that initially, the **earth and the moon formed a single rapidly rotating body**. The whole mass became a **dumb-bell-shaped body** and eventually it broke. It was also suggested that the material forming the moon was separated from

the **depression occupied by the Pacific Ocean**.

- **The Big Splat (the giant impact):** A one to three times size of mars, body collided into the earth shortly after the earth was formed and blasted a large part of the earth into space. This **portion of blasted material** then continued to orbit the earth and eventually formed into the present moon about **4.44 billion years ago**.

Evolution of the Earth:

Initially the earth was a barren, rocky and hot object with a thin atmosphere of **hydrogen and helium**. The life evolved on the surface of the earth **between the 4,600 million years** and the present. The earth has a **layered structure**. The material is not uniform from the outermost end of the atmosphere to the centre of the earth.

Evolution of the Lithosphere:

- In primordial stage, the earth was volatile. Due to **gradual increase in density** the temperature inside it has increased. As a result, the material inside the earth started getting separated depending on



their densities which allowed **heavier materials** (like iron) to **sink** towards the centre of the earth and the lighter ones to move towards the surface.

- With passage of time, **material got cooled** further and solidified and condensed into a smaller size which led to the development of the outer surface in the form of a crust.
- The earth was further heated up during the formation of the moon. Due to differentiation, the earth forming material got separated into **different layers**.
- The earth has **layers like crust, mantle, outer core, and inner core** from the surface to the central parts. The **density of the material increases from the crust to the core**.

Evolution of Atmosphere and Hydrosphere:

The present earth's atmosphere **composition** is chiefly contributed by **nitrogen** and **oxygen**. There are **three stages in the evolution** of the present atmosphere.

- **First Stage:** It is marked by the **loss of primordial atmosphere**.
 - The primordial atmosphere, consisted of **hydrogen and helium**, is supposed to have been stripped off as a result of the solar winds.
- **Second Stage:** The hot interior of the earth contributed to the evolution of the atmosphere.
 - During the cooling of the earth, **gases and water vapour were released** from the interior solid earth.

- The **early atmosphere** largely contained water vapour, nitrogen, carbon dioxide, methane, ammonia and very little of free oxygen.

- **Degassing** is the process through which the gases were outpoured from the interior.

- **Continuous volcanic eruptions** contributed water vapour and gases to the atmosphere.

- The carbon dioxide in the atmosphere got dissolved in rainwater and the **temperature further decreased** causing more condensation and more rains.

- The **rainwater falling** onto the surface got collected in the depressions to give **rise to oceans**. The oceans were formed within 500 million years from the formation of earth.

- **Third Stage:** The atmosphere **composition was modified** by the living world through **photosynthesis**.

- The **process of photosynthesis got evolved around 2,500-3,000 million years** before the present.

- Oceans began to have the contribution of oxygen through photosynthesis.

- Eventually, oceans were saturated with oxygen, and **2,000 million years ago, oxygen began to flood the atmosphere**.

Origin of Life: The last phase in the evolution of the earth relates to the origin and evolution of life.

- Modern scientists refer to the origin of life as a kind of **chemical reaction**

which first generated complex organic molecules and assembled them in such way that they could **duplicate themselves** converting inanimate matter into living substance.

- The record of life that existed on this planet in different periods is found in rocks in the form of fossils.
- The **microscopic structures** closely related to the present form of **blue algae** have been found in geological formations much older than some 3,000 million years.
- It can be assumed that **life began to evolve sometime 3,800 million years ago**.

Table 2.2: Geological Time Scale

Eons	Era	Period	Epoch	Age/ Years Before Present	Life/ Major Events
	Cainozoic (From 65 million years to the present times)	Quaternary	Holocene Pleistocene	0 - 10,000 10,000 - 2 million	Modern Man Homo Sapiens
		Tertiary	Pliocene Miocene	2 - 5 million 5 - 24 million	Early Human Ancestor Ape: Flowering Plants and Trees
			Oligocene Eocene Palaeocene	24 - 37 million 37 - 58 Million 57 - 65 Million	Anthropoid Ape Rabbits and Hare Small Mammals: Rats - Mice
	Mesozoic 65 - 245 Million Mammals	Cretaceous Jurassic Triassic		65 - 144 Million 144 - 208 Million 208 - 245 Million	Extinction of Dinosaurs Age of Dinosaurs Frogs and turtles
	Palaeozoic 245 - 570 Million	Permian		245 - 286 Million	Reptile dominate-replace amphibians
		Carboniferous		286 - 360 Million	First Reptiles: Vertebrates: Coal beds
		Devonian Silurian		360 - 408 Million 408 - 438 Million	Amphibians First trace of life on land: Plants
		Ordovician Cambrian		438 - 505 Million 505 - 570 Million	First Fish No terrestrial Life : Marine Invertebrate
Proterozoic Achean Hadean	Pre-Cambrian 570 Million -4,800 Million			570-2,500 Million 2,500-3,800 Million 3,800-4,800 Million	Soft-bodied arthropods Blue green Algae: Unicellular bacteria Oceans and Continents form - Ocean and Atmosphere are rich in Carbon dioxide
Origin of Stars Supernova Big Bang	5,000- 13,700 Million			5,000 Million 12,000 Million 13,700 Million	Origin of the sun Origin of the universe



Interesting Points:

- **Light year:** It is a **measure of distance** and not of time. Light travels at a speed of 300,000 km/second. The **distance the light will travel in one year** is taken to be one light year. This equals to 9.461×10^{12} km.
- The **mean distance** between the **sun and the earth** is 149,598,000 km. In terms of light years, it is **8.311 minutes**.
- Till recently (August 2006), **Pluto** was also considered a planet. However, in a meeting of the **International Astronomical Union**, a decision was taken that Pluto like other celestial objects (2003 UB313) discovered in recent past may be called '**dwarf planet**'.



3

Interior of the Earth

The **interior of the earth can be understood only by indirect evidence** as no one can reach the earth's interior. The configuration of the surface of the earth is largely a product of the processes operating in the interior of the earth. Human life is largely influenced by the physiography of the region.

Sources of Information about the Interior

Direct Sources:

- **Surface rock or rocks from mining:** These are the **most easily available** solid earth material. Gold mines in South Africa are as deep as 3 - 4 km.
- **Projects to penetrate deeper depths:** Scientists are working on two major projects such as “**Deep Ocean Drilling Project**” and “**Integrated Ocean Drilling Project**”. The deepest drill at Kola, in Arctic Ocean, has so far reached a depth of 12 km.
- **Volcanic eruption:** It forms another source of **obtaining direct information**.

Indirect Sources:

- **Analysis of properties of matter:** It **indirectly provides information** about the interior such as temperature and pressure increase with the increasing distance from the surface towards the interior in deeper depths.
- **Meteors:** These reach the earth, and **their material and structure are similar to earth**.
- **Gravitation force (g):**
 - It is **different** at **different latitudes** on the surface. It is **greater near the poles and less at the equator**

because distance from the centre at the equator is greater than poles.

- The reading of the gravity at different places is **influenced by many factors** such as the mass of the material, uneven distribution of mass of the material etc.
- The **difference between these readings** and the expected value is **called gravity anomaly** which gives information about the distribution of mass of the material in the earth's crust.

- **Magnetic surveys:** It provides information about the **distribution of magnetic materials** in the crustal portion.
- **Seismic activity:** The study of seismic waves provides a **complete picture of the layered interior**.

Earthquake:

It is **shaking of the earth**. It is a **natural event** and is caused due to **release of energy** which generates waves that travel in all directions. The **reasons for shaking of the earth:**

- The **release of energy** occurs along a **fault** which is a sharp break in the crustal rocks.
- **Rocks along a fault tend to move in opposite directions** and as the overlying rock strata press them, the friction locks them together.
- Their tendency to move apart at some point of time **overcomes the friction**. As a result, the blocks get deformed and eventually, **they slide past one another abruptly**. This causes a release directly of energy, and the **energy waves travel in all directions**.

- **Focus of an earthquake (hypocentre):** It is the point **where the energy is released**.
- **Epicentre:** It is the **point on the surface, nearest to the focus**. It is the first one to experience the waves. It is a **point above the focus**.

Earthquake Waves:

All-natural Earthquakes take place in the lithosphere.

- The velocity of waves changes as they travel through materials with different densities. **The denser the material, the higher is the velocity.**
- **Reflection** causes waves to rebound whereas **refraction** makes waves move in different directions.

Earthquake waves are basically of two types:

- **Body Waves:** These waves are generated due to the **release of energy** at the **focus** and move **in all directions travelling through the body** of the earth. There are two types of body waves.
 - **P-waves:** These **move faster** and are the **first to arrive at the surface**. These are also called '**primary waves**'. They are **similar to sound waves**. They travel through **gaseous, liquid, and solid materials**.
 - **S-waves:** These **arrive** at the surface with some **time lag**. These are called **secondary waves**. They can **travel only through solid materials** and this characteristic has helped scientists to understand the structure of the interior of the earth.
- **Surface Waves:** The body waves **interact with the surface rocks** and generate new set of waves called **surface**

waves. These waves **move along the surface**. They are the **last to report on seismograph**. They are **more destructive** as they cause displacement of rocks, and hence, the collapse of structures occurs.

Propagation of the Earthquake Waves:

Different types of earthquake waves travel in different manners. As they move or propagate, they cause vibration in the body of the rocks through which they pass.

- **P-waves vibrate parallel** to the **direction of the wave** which exerts pressure on the material in the direction of the propagation. Hence, it **creates density differences** in the material leading to stretching and squeezing of the material.
- The direction of vibrations of **S-waves** is **perpendicular to the wave direction** in the vertical plane. Hence, they **create troughs and crests** in the material through which they pass.

Emergence of Shadow Waves:

Shadow Zone: They are zones where the **waves** are **not reported**. The study of different events reveals that for **each earthquake**, there exists an altogether **different shadow zone**.

- It was observed that seismographs located at any distance **within 105° from the epicentre**, recorded the arrival of **both P and S-waves**.
- The seismographs located **beyond 145° from epicentre, record the arrival of P-waves, but not that of S-waves**. Thus, a zone **between 105° and 145°** from epicentre was identified as the **shadow zone** for **both the types of waves**.

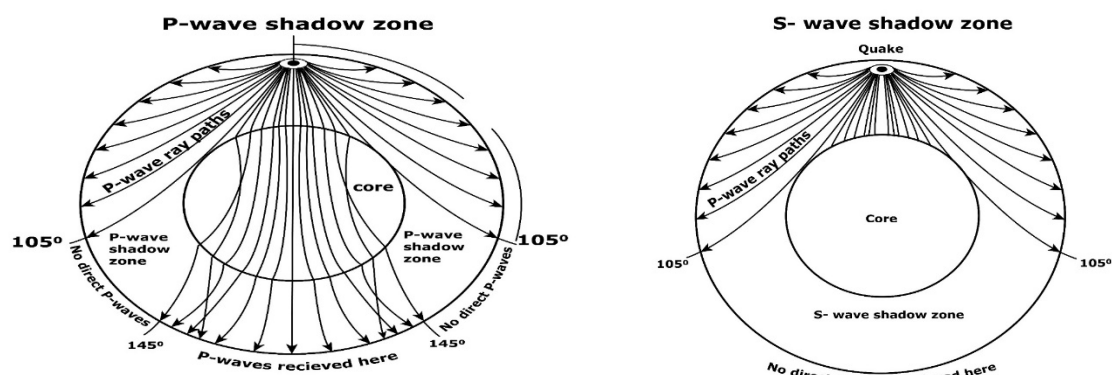


Fig. 3.1: (a) and (b) Earthquake Shadow Zones

- The entire zone **beyond 105°** does **not receive S-waves**. The **shadow zone of S-wave is much larger than that of the P-waves**. The shadow zone of S-waves is not only larger in extent, but it is also a little over 40 per cent of the earth surface.
- The **shadow zone of P-waves** appears as a **band** around the earth **between 105° and 145°** away from the epicentre.

Types of Earthquake:

- **Tectonic Earthquake:** They are most common ones and are generated due to **sliding of rocks** along a fault plane.
- **Volcanic Earthquake:** They are a **special class of tectonic earthquake** and these are confined to **areas of active volcanoes**.
- **Collapse Earthquake:** The roofs of **underground mines collapse** in the areas of intense mining activity which cause minor tremors.

- **Explosion Earthquake:** Ground shaking occur due to the **explosion of chemical or nuclear devices**.
- **Reservoir induced Earthquake:** These earthquakes occur in the areas of **large reservoirs**.

Measuring of Earthquakes: The earthquake events are scaled either according to the **magnitude** or **intensity** of the **shock**.

- **Richter Scale (Magnitude Scale):** The **magnitude relates to the energy** released during the quake. The magnitude is expressed in numbers, **0-10**.
- **Mercalli Scale (Intensity Scale):** It is **named after Mercalli**, an Italian seismologist. It takes into account the **visible damage** caused by the event and range of intensity scale is from **1-12**.

Effects of earthquake waves: Earthquake is a natural hazard therefore following effects can be seen:

1. Ground Shaking	5. Ground lurching	9. Structural collapse
2. Differential ground settlement	6. Avalanches	10. Ground displacement
3. Land and mud slides	7. Floods from dam and levee failures	11. Fires
4. Soil liquefaction	8. Falling objects	12. Tsunami

The first six listed above have some bearings upon landforms, while others may be considered the effects causing immediate concern to the life and properties of people in the region.

- The effect of **tsunami would occur only if the epicentre of the tremor is below oceanic waters** and the magnitude is sufficiently high. **Tsunamis** are **waves generated by the tremors** and not an earthquake in itself.

Structure of the Earth

The Crust:

- It is the **outermost solid part** of the earth and is brittle in nature.
- Its thickness varies under the oceanic and continental areas.
- **Oceanic crust** is **thinner** as compared to the continental crust. The mean thickness of **oceanic crust** is **5 km**

whereas that of the **continental** is **around 30 km**.

- The continental crust is **thicker in the areas of major mountain systems**. It is as much as 70 km thick in the Himalayan region.

The Mantle:

- It is the portion of the interior **beyond the crust** and extends from **Moho's discontinuity** to a **depth of 2,900 km**.
- **Asthenosphere:** It is the **upper portion** of the mantle. The word *astheno* means weak. It is considered to be extending **up to 400 km**. It is the **main source of magma** that finds its way to the surface during volcanic eruptions.
- **Lithosphere:** It is the **crust and the uppermost part** of the mantle and its thickness ranges from **10-200 km**.
- The **lower mantle** extends beyond the asthenosphere and is in **solid state**.

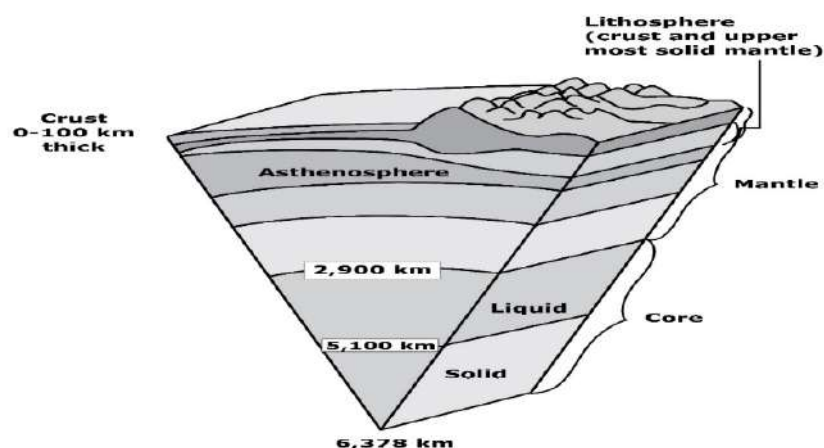


Fig. 3.2: The interior of the Earth

The Core:

- The core mantle boundary is located at the depth of 2,900 km.
- The **outer core** is in **liquid state** while the **inner core** is in **solid state**.
- **Nife layer:** The core is made up of very **heavy material** mostly constituted by **nickel and iron**.

Volcanoes and Volcanic Landforms:

A volcano is a place where **gases, ashes and/or molten rock material (lava) escape** to the ground.

- **Active Volcano:** It is a volcano if the materials mentioned are being **released** or have been released out in the **recent past**.
- From asthenosphere the molten rock materials find their way to the surface. The **material** in the **upper mantle portion** is called **magma**. Once it starts moving towards the crust or it **reaches the surface**, it is referred to as **lava**.
- The material that reaches the ground includes lava flows, pyroclastic debris,

volcanic bombs, ash and dust and gases such as nitrogen compounds, sulphur compounds and minor amounts of chlorine, hydrogen and argon.

Classification of Volcanos: Volcanoes are classified based on **nature of eruption and the form developed at the surface**.

Shield Volcanoes:

- Barring the basalt flows, they are the **largest of all the volcanoes** on the earth. For example - The Hawaiian volcanoes.
- These volcanoes are mostly **made up of basalt**, a type of lava that is very fluid when erupted. For this reason, these volcanoes are **not steep**.
- They become explosive if somehow water gets into the vent; otherwise, they are characterised by **low-explosivity**.
- The **upcoming lava** moves in the form of a **fountain** and throws out the cone at the top of the vent and develops into **cinder cone**.



Fig. 3.3: Shield Volcano

Composite Volcanoes:

- These volcanoes are characterised by **eruptions of cooler and more viscous lavas** than basalt.
- These volcanoes often result in **explosive eruptions**.
- Along with lava, large quantities of pyroclastic material and ashes find their way to the ground which **accumulates in the vicinity of the vent** openings leading to formation of layers, and this makes the mounts appear as composite volcanoes.



Fig. 3.4: Composite volcano

Caldera:

- These are the **most explosive** of the earth's volcanoes. They are usually so

explosive that when they erupt, they tend to **collapse on themselves** rather than building any tall structure.

- The **collapsed depressions** are called **calderas**. Their explosiveness indicates that the **magma chamber** supplying the lava is not only huge but is also in **close vicinity**.

Flood Basalt Province:

- These volcanoes **outpour highly fluid lava** that flows for long distances.
- There can be a series of flows with some flows attaining thickness of more than 50 m. Individual flows may extend for hundreds of km.
- **Deccan Traps** covering most of the **Maharashtra plateau** are a larger **flood basalt province**.

Mid Oceanic Ridge Volcanoes:

- These volcanoes occur in the **oceanic areas**.
- There is a system of mid-ocean ridges more than 70,000 km long that **stretches through all the ocean basins**. The **central portion of this ridge experiences frequent eruptions**.

Volcanic Landforms:

Intrusive landforms:

- The lava that is released during volcanic eruptions on cooling develops into igneous rocks.
- The cooling may take place either on reaching the surface or within the crustal portion.
- Depending on the location of the cooling of the lava, igneous rocks are classified as **volcanic rocks (cooling at**

the surface) and plutonic rocks (cooling in the crust).

- The lava that **cools within the crustal portions** assumes different forms. These forms are called **intrusive forms**.

Batholiths:

- A large body of **magmatic material** that **cools in the deeper depth** of the crust develops in the form of large domes.
- They appear on the surface only after the denudational processes remove the overlying materials.
- They cover large areas, and at times, assume depth that may be several km.
- These are **granitic bodies**.

- Batholiths are the **cooled portion of magma chambers**.

Lacoliths:

- These are **large dome-shaped** intrusive bodies with **a level base** and connected by a **pipe-like conduit** from below.
- It resembles the surface volcanic domes of composite volcano, only these are located at deeper depths.
- The Karnataka plateau is spotted with domal hills of granite rocks. Most of these, now exfoliated, are examples of lacoliths or batholiths.

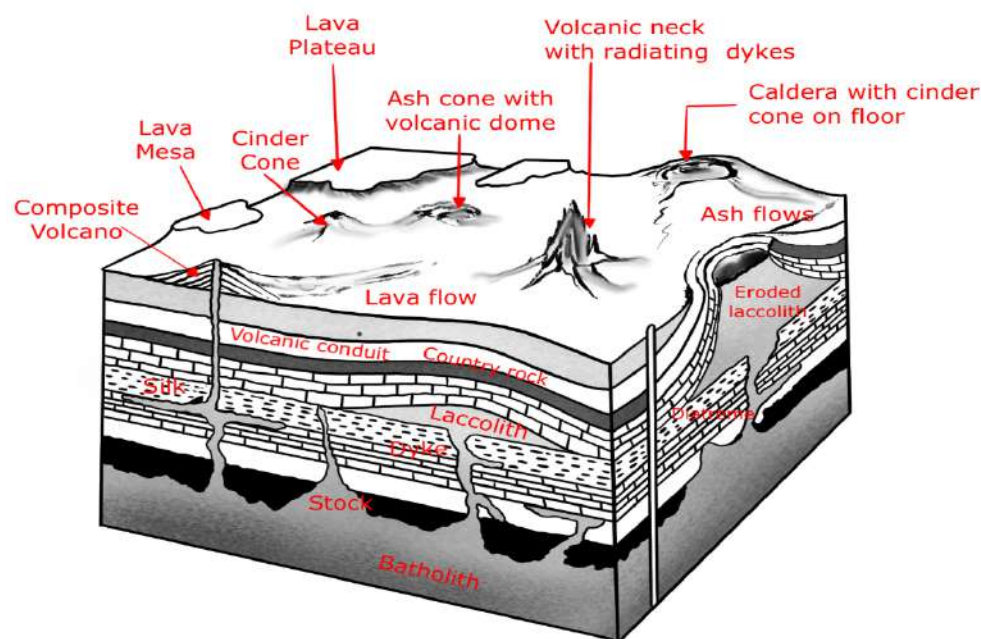


Fig. 3.5: Volcanic landforms

Lapolith:

- Lava moves upwards and a portion of the same may tend to move in a horizontal direction wherever it finds a weak plane.

It may get rested in different forms.

- In case it develops into a **saucer shape**, concave to the sky body, it is called lapolith.

Phacolith:

- A **wavy mass of intrusive rocks**, at times, is found at the base of **synclines** or at the top of **anticline** in folded igneous country.
- Such wavy materials have a definite conduit to source beneath in the form of magma chambers (subsequently developed as batholiths). These are called the phacoliths.

Sills or Sheets:

- The near **horizontal bodies** of the intrusive igneous rocks are called sill or sheet, depending on the thickness of the material.
- The **thinner ones** are called **sheets** while the **thick horizontal deposits** are called **sills**.

Dykes:

- When the lava makes its way through cracks and the fissures developed in the

land, it solidifies almost **perpendicular to the ground**.

- It gets cooled in the same position to develop a **wall-like structure** called **dykes**.
- These are the most commonly found intrusive forms in the western Maharashtra area. These are considered the feeders for the eruptions that led to the development of the Deccan traps.

Interesting Points:

- The **Earth's radius** is approximately **6,370 km**.
- **Lithosphere** refers to the portion of depth up to 200 km from the surface of the Earth.
- The **'seismograph'** is an instrument which **records the seismic waves** reaching the surface.



4

Distribution of Oceans and Continents

Continents cover 29 per cent of the surface of the earth and the **remainder is under oceanic waters**. The positions of the continents and the ocean bodies have not been the same in the past and will not continue to enjoy their present positions in times to come.

Continental Drift Theory:

The shape of the coastline of the Atlantic Ocean on either side of the ocean is symmetrical. The scientists considered the possibility of the two Americas, Europe, and Africa, to be once joined together.

- **Abraham Ortelius:** The Dutch map maker first proposed such a possibility in 1596.
- **Antonio Pellegrini:** He drew a map showing the three continents together.
- **Alfred Wegener:** A German meteorologist put forth a comprehensive argument in the form of “**the continental drift theory**” in **1912**. It was **regarding the distribution of the oceans and the continents**.
 - According to Wegener, **all the continents formed a single continental mass and mega ocean surrounded the same**.
 - The super continent was named **Pangea** and the mega-ocean was called **Panthalasa**.
 - He argued that, **around 200 million years ago**, the **Pangaea began to split** and first broke into **two large continental masses** as **Laurasia** and **Gondwanaland** forming the northern and southern components, respectively.

- Subsequently, **Laurasia** and **Gondwanaland** continued to break into various smaller continents that exist today.

Evidence in Support of the Continental Drift:

- **The Matching of Continents (Jig-Saw-Fit):** The shorelines of Africa and South America have a remarkable and unmistakable match.
- **Rocks of Same Age Across the Oceans:**
 - The **radiometric dating** methods have facilitated correlating the rock formation from different continents across the vast ocean.
 - The belt of ancient rocks of 2,000 million years from Brazil coast matches with those from western Africa.
 - The earliest marine deposits along the coastline of South America and Africa are of the Jurassic age. This suggests that the ocean did not exist prior to that time.
- **Tillite:**
 - It is the **sedimentary rock** formed out of deposits of glaciers.
 - The Gondwana system of sediments from India is known to have its counterparts in six different landmasses of the Southern Hemisphere. At the base, the system has thick tillite indicating extensive and prolonged glaciation.
 - Counterparts of this succession are found in **Africa, Falkland Island, Madagascar, Antarctica and Australia**.
 - The glacial tillite provides

unambiguous evidence of **paleoclimates** and also **drifting of continents**.

- **Placer Deposits:**

- The occurrence of rich **placer deposits of gold** in the **Ghana coast** and the **absolute absence** of **source rock** in the region is an amazing fact.
- The gold bearing veins are in Brazil and it is obvious that the gold deposits of the Ghana are derived from the Brazil plateau when the two continents lay side by side.

- **Distribution of Fossils:**

- The **Lemurs** occur in India, Madagascar and Africa led some to consider a contiguous landmass '**Lemuria**' linking these three landmasses.
- **Mesosaurus** was a small reptile adapted to shallow brackish water. The skeletons of these are found only in two localities: Southern Cape province of South Africa and Iraver formations of Brazil.

Force for Drifting: Wegener suggested that the movement responsible for the drifting of the continents was caused by:

- **The Polar-fleeing force:** It relates to the **rotation of the earth**.
- **The Tidal force:** It is due to the **attraction of the moon and the sun** that develops tides in oceanic waters. Wegener believed that these forces would become effective when applied over many million years.

Post Drift Studies:

A number of discoveries during the post–World War II period added new information to geological literature. The information collected from **the ocean floor mapping** provided new dimensions for the study of distribution of oceans and continents.

Convectional Current Theory:

- **Arthur Holmes** in 1930s discussed the possibility of convection currents operating in the **mantle portion**. These currents are **generated** due to **radioactive elements** causing thermal differences in the mantle portion.
- He argued that there exists a system of such currents in the entire mantle portion.
- This was an attempt to provide an explanation to the issue of force, on the basis of which contemporary scientists discarded the continental drift theory.

Mapping of the Ocean Floor:

- Expeditions to map the oceanic floor in the post–World War II period provided a detailed picture of the ocean relief and indicated the existence of submerged mountain ranges as well as deep trenches, mostly located closer to the continent margins.

Ocean Floor Configuration: The ocean floor may be segmented into three major divisions based on the depth as well as the forms of relief.

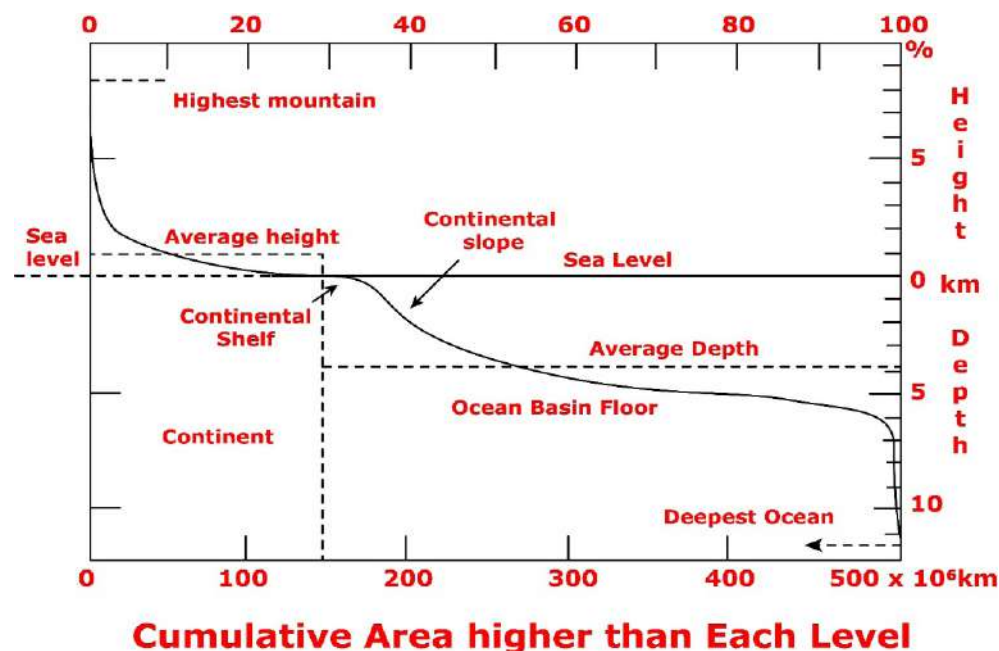


Fig. 4.1: Ocean Floor

- **Continental Margins:**
 - These form the **transition** between **continental shores and deep-sea basins**.
 - They include continental shelf, continental slope, continental rise and deep-oceanic trenches.
- **Abyssal Plains:**
 - These are extensive plains that lie **between the continental margins and mid-oceanic ridges**.
 - These are the areas where the continental **sediments** that move beyond the margins get **deposited**.
- **Mid-Oceanic Ridges:**
 - This forms an **interconnected chain of mountain system** within the ocean. It is the longest mountain-chain on the surface of the earth.
 - It is characterised by a central rift system at the crest, a fractionated

plateau and flank zone all along its length.

- The **rift system at the crest** is the **zone of intense volcanic activity**.

Concept of Sea Floor Spreading:

The mapping of the ocean floor and palaeomagnetic studies of rocks from oceanic regions revealed the following facts:

- It was realised that all **along the mid-oceanic ridges, volcanic eruptions are common**, and they bring huge amounts of lava to the surface in this area.
- The **rocks equidistant** on either side of the crest of mid-oceanic ridges show **remarkable similarities** in terms of period of formation, chemical compositions and magnetic properties.

Distribution of Earthquakes and Volcanoes:

- In general, the foci of the earthquake in the areas of mid-oceanic ridges are at shallow depths whereas along the Alpine-Himalayan belt as well as the rim of the Pacific, the earthquakes are deep-seated ones.
- The map of volcanoes also shows a similar pattern. The **rim of the Pacific** is also called '**rim of fire**' due to the existence of active volcanoes in this area.

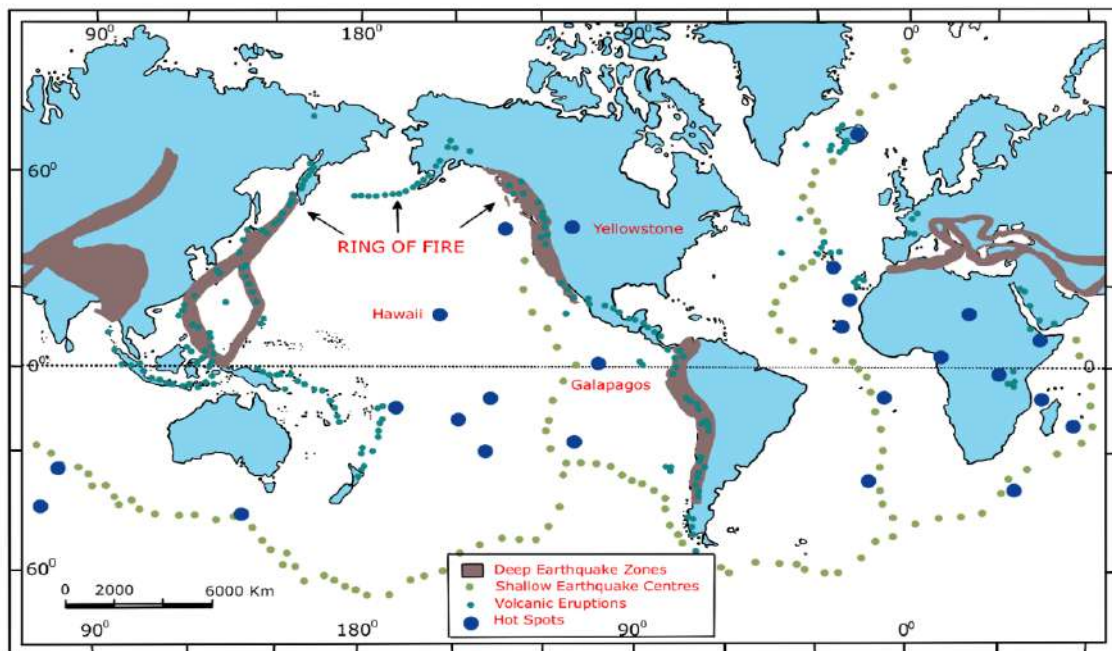


Fig. 4.2: Distribution of the earthquakes and volcanoes

- **The age of the rocks increases as one moves away from the crest.** Rocks closer to the mid-oceanic ridges have normal polarity and are the youngest.
- **The ocean crust rocks are much younger than the continental rocks.** The age of rocks in the oceanic crust is nowhere more than 200 million years old. Some of the continental rock formations are as old as 3,200 million years.
- The **sediments** on the **ocean floor** are unexpectedly **very thin**. Nowhere was the sediment column found to be older than 200 million years.
- The **deep trenches** have **deep-seated earthquake** occurrences while in the mid-oceanic ridge areas, the quake focus have shallow depths. These facts and a detailed analysis of magnetic properties of the rocks on

either side of the mid-oceanic ridge led **Hess (1961)** to propose his hypothesis, known as the “**sea floor spreading**”.

- Hess argued that **constant eruptions** at the crest of oceanic ridges cause the

rupture of the oceanic crust and the new lava wedges into it, pushing the oceanic crust on either side.

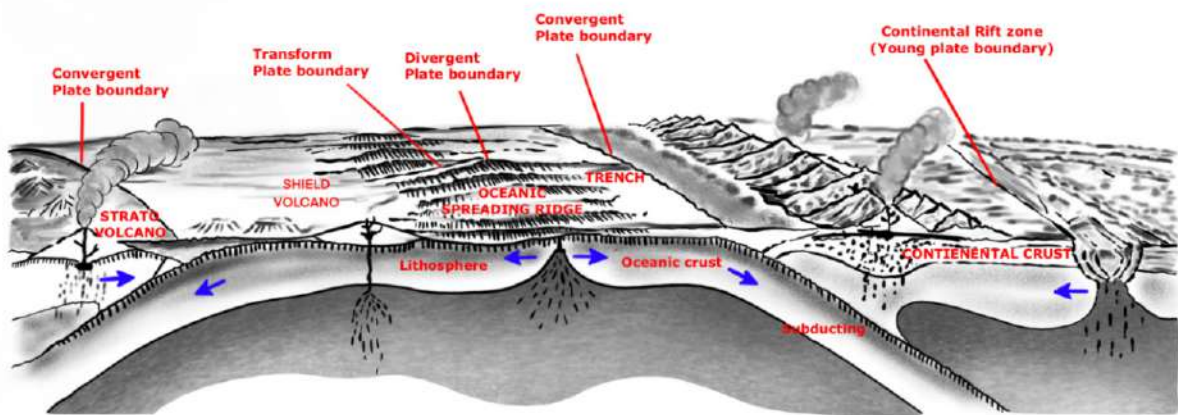


Fig. 4.3: Sea Floor Spreading

- The younger age of the oceanic crust and the spreading of one ocean does not cause the shrinking of the other, made Hess think about the **consumption of the oceanic crust**.
- He further said that the **ocean floor** that gets pushed due to volcanic eruptions at the crest, **sinks down at the oceanic trenches and gets consumed**.
- **Plate Tectonics:**
It was in 1967, **McKenzie, Parker and Morgan**, independently collected the available ideas and came out with concept of Plate Tectonics.
- **A tectonic plate (lithospheric plate):** It is a massive, irregularly shaped slab of solid rock, generally **composed of both continental and oceanic lithosphere**.
- Plates move **horizontally** over the asthenosphere as **rigid units**.
- The **lithosphere** includes the **crust and top mantle** with its thickness range varying between 5 and 100 km in oceanic parts and about 200 km in the continental areas.
- A plate may be **referred to as the continental plate or oceanic plate** depending on which of the two occupy a larger portion of the plate.
- The theory of plate tectonics proposes that the earth's lithosphere is divided into **seven major and some minor plates**.
- Young Fold Mountain ridges, trenches, and/or faults surround these major plates.
- It is not the continent that moves as believed by Wegener. Continents are

part of a plate and it is the **plate that moves**.

- Later discoveries reveal that the continental masses, resting on the plates, have been wandering all through the geological period, and **Pangaea was a result of converging of different**

continental masses that were parts of one or the other plates.

- Position of the Indian subcontinent (mostly Peninsular India) is traced with the help of the rocks analysed from the Nagpur area.

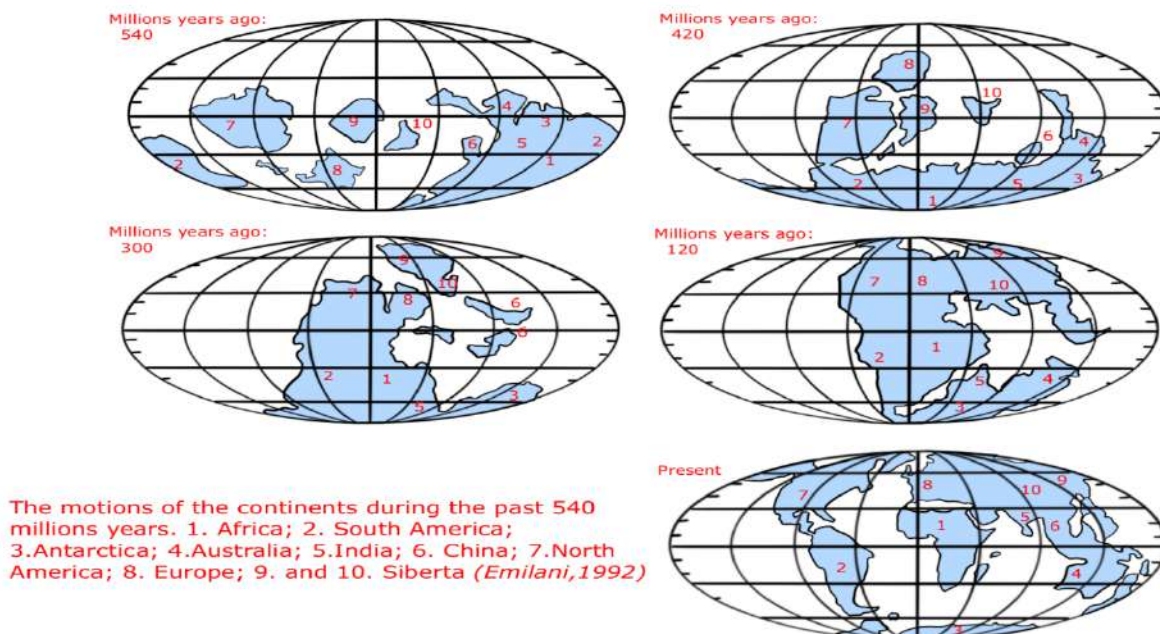


Fig. 4.4: Position of Continents through Geological Past

Types of Plate Boundaries

- **Divergent Boundaries:**
 - Where **new crust is generated** as the plates pull away from each other.
 - The sites where the **plates move away** from each other are called **spreading sites**.
 - **Example:** The Mid-Atlantic Ridge. At this plate, the American Plate(s) is/are separated from the Eurasian and African Plates.
- **Convergent Boundaries:**
 - Where the **crust is destroyed** as one plate dived under another.
 - The **location where the sinking of a plate** occurs is called a **subduction zone**.
 - There are **three ways** in which convergence can occur. These are:
 - ◆ Between an oceanic and continental plate.
 - ◆ Between two oceanic plates.
 - ◆ Between two continental plates.

Major and Minor Plates

Major Plates:

- Antarctica and the surrounding oceanic plate
- North American (with western Atlantic floor separated from the South American plate along the Caribbean islands) plate
- South American (with western Atlantic floor separated from the North American plate along the Caribbean islands) plate
- Pacific plate
- India-Australia-New Zealand plate
- Africa with the eastern Atlantic floor plate
- Eurasia and the adjacent oceanic plate

Minor Plates:

- **Cocos plate:** Between Central America and Pacific plate
- **Nazca plate:** Between South America and Pacific plate
- **Arabian plate:** Mostly the Saudi Arabian landmass
- **Philippine plate:** Between the Asiatic and Pacific plate
- **Caroline plate:** Between the Philippine and Indian plate (North of New Guinea)
- **Fuji plate:** North-east of Australia

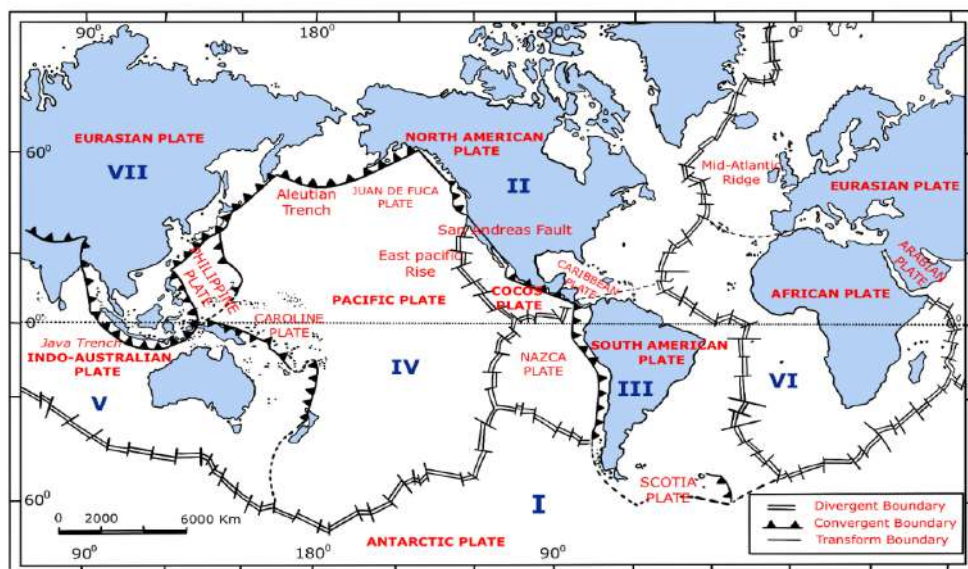


Fig. 4.5: Major and Minor Plates of the world

Transform Boundaries:

- Where the **crust is neither produced nor destroyed** as the plates slide horizontally past each other.
- **Transform faults** are the **planes of separation** generally perpendicular to the mid-oceanic ridges.
- As the eruptions do not take all along the entire crest at the same time, there is a **differential movement** of a **portion of the plate** away from the axis of the earth.
- Also, the rotation of the earth has its effect on the separated blocks of the plate portions.

Rates of the Plate Movements:

- The rate of plate movement is **determined by the strips of normal and reverse magnetic field** that parallel the mid-oceanic ridges.
- These rates vary considerably.
- The **Arctic Ridge** has the **slowest rate** (less than 2.5 cm/yr), and the **East Pacific Rise** near Easter Island, in the South Pacific, has the **fastest rate** (more than 15 cm/yr).

Force for the Plate Movement:

- At the time that Wegener proposed his theory of continental drift, most scientists believed that the earth was a solid, motionless body.
- However, concepts of sea floor spreading, and the unified theory of plate tectonics have emphasised that both the surface of the earth and the interior are dynamic.
- The mobile **rock beneath the rigid plates** is believed to be **moving in a circular**

manner.

- The heated material rises to the surface, spreads and begins to cool, and then sinks back into deeper depths. This cycle is repeated over and over and called **convection cell or convective flow**.
- Heat within the earth comes from two main sources: **radioactive decay** and **residual heat**.
- **Arthur Holmes** first considered this idea, which later influenced Harry Hess' thinking about seafloor spreading.
- The **slow movement of hot, softened mantle** that lies below the rigid plates is **the driving force behind the plate movement**.

The Indian Plate:

The Indian plate includes **Peninsular India** and the **Australian continental portions**.

- The **subduction zone** along the Himalayas forms the northern plate boundary in the form of **continent-continent convergence**.
- In the east, it **extends** through **Rakinyoma Mountains of Myanmar** towards the island arc along the Java Trench.
- The **eastern margin** is a **spreading site** lying to the east of Australia in the form of an oceanic ridge in SW Pacific.
- The **Western margin** follows **Kirthar Mountain of Pakistan**. It further extends along the Makrana coast and joins the spreading site from the Red Sea rift south-eastward along the Chagos Archipelago.
- The boundary between India and the Antarctic plate is also marked by oceanic

ridge (divergent boundary) running in roughly W-E direction and merging into the spreading site, a little south of New Zealand.

Movement of Indian Plate:

- India was a large island situated off the Australian coast. The **Tethys Sea** separated it from the Asian continent till about 225 million years ago.
- India is supposed to have started her northward journey about 200 million years ago at the time **when Pangaea broke**.
- **India collided with Asia** about 40-50 million years ago causing rapid uplift of the Himalayas.
- During the movement of the Indian plate towards the Eurasian plate, a major event that occurred was the outpouring of lava and **formation of the Deccan Traps**.
- From 40 million years ago and thereafter, the **event of formation of the Himalayas** took place.

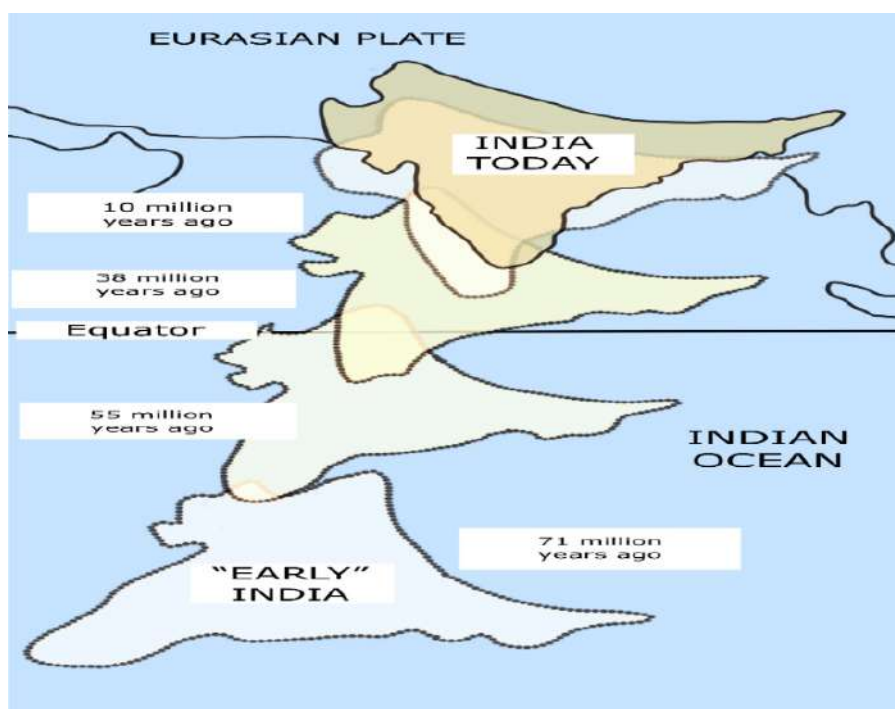


Fig. 4.6: Movement of the Indian plate

Interesting Point:

- About **140 million years** before the present, the **Indian subcontinent** was located as south as **50°S latitude**.



Unit III: Landforms



5

Minerals and Rocks

The earth is composed of various kinds of elements. The elements in the earth's crust are rarely found exclusively but are usually combined with other elements to make various substances. These substances are recognised as minerals.

Mineral:

- A mineral is a **naturally occurring organic and inorganic substance**, having an orderly atomic structure and a definite chemical composition and physical properties.
- A mineral is **composed of two or more elements** but, **sometimes single element** minerals like sulphur, copper, silver, gold, graphite, etc. are found.

Elements of Earth Crust:

- **Major Elements:** About **98 per cent of the total crust of the earth** is composed of eight elements like oxygen, silicon, aluminium, iron, calcium, sodium, potassium and magnesium.
- **Minor Elements:** The rest is constituted by titanium, hydrogen, phosphorous, manganese, sulphur, carbon, nickel and other elements.
- There are at least 2,000 minerals that have been named and identified in the earth crust but almost all the commonly occurring ones are related to **six major mineral groups** that are known as **major rock forming minerals**.
- **Basic source of all Minerals:** It is the **hot magma** in the interior of the earth. When magma cools, crystals of minerals appear, and a systematic series of minerals are formed in sequence to **solidify to form rocks**.

Physical Characteristics of Minerals:

- **External crystal form:** It is determined by **internal arrangement** of the molecules - cubes, octahedrons, hexagonal prisms, etc.
- **Cleavage:** It is **tendency to break in given directions** producing relatively plane surfaces. This is **due to internal arrangement** of the molecules. A mineral may cleave in one or more directions and at any angle to each other.
- **Fracture:** The internal molecular arrangement is so complex that there are no planes of molecules and the **crystal will break in an irregular manner**, not along planes of cleavage.
- **Lustre:** It is the **appearance of a material** without regard to colour and each mineral has a distinctive lustre like metallic, silky, glossy etc.
- **Colour:** Some minerals have **characteristic colour** determined by their molecular structure such as malachite, azurite. Some minerals are coloured by impurities such as quartz.
- **Streak:** The **colour of the ground powder** of any mineral. It may be of the same colour as the mineral or may differ. Malachite is green and gives green streak, fluorite is purple or green but gives a white streak.
- **Transparency:**
 - **Transparent:** Light rays **pass through** so that objects can be seen plainly.
 - **Translucent:** Light rays **pass through but will get diffused** so that objects cannot be seen.
 - **Opaque:** Light **will not pass** at all.
- **Structure:** It is the **particular arrangement** of the individual crystals such as fine, medium or coarse grained.

- **Hardness:** It is the **relative resistance while getting scratched**. Ten minerals are selected to measure the **degree of hardness from 1-10**:

- They are: 1. talc; 2. gypsum; 3. calcite; 4. fluorite; 5. apatite; 6. feldspar; 7. quartz; 8. topaz; 9. corundum; 10. diamond.
- Compared to this for example, a fingernail is 2.5 and glass or knife blade is 5.5.

- **Specific Gravity:** The **ratio** between the **weight of a given object** and the **weight of an equal volume of water**.

Metallic minerals: These minerals **contain metal content** and can be subdivided into three types:

- **Precious metals:** Gold, silver, platinum, etc.
- **Ferrous metals:** Iron and other metals often mixed with iron to form various kinds of steel.
- **Non-ferrous metals:** It include metals like copper, lead, zinc, tin, aluminium, etc.

Non-metallic minerals: These minerals **do not contain metal content** such as Sulphur, Phosphates, and Nitrates. Cement is a mixture of non-metallic minerals.

Rocks:

- A rock is an **aggregate of one or more minerals**. The earth's crust is composed of rocks.
- Rocks do not have definite composition of mineral constituents. **Feldspar** and **quartz** are the most **common minerals** found in rocks.

Types of Rocks based on their mode of formation

Igneous Rocks (Primary Rocks):

- Igneous rocks **form out of magma and lava** from the interior of the earth.
- When **magma** in its upward movement cools and turns into solid form it is called **igneous rock (*ignis* – in Latin means 'Fire')**.
- They are classified based on texture which depends upon size and arrangement of grains.
- If molten material is cooled slowly at **great depths**, mineral grains may be **very large**.
- **Sudden cooling** (at the surface) results in small and smooth grains.
- **Intermediate conditions** of cooling result in intermediate sizes of grains.
- **Examples:** Granite, gabbro, pegmatite, basalt, volcanic breccia and tuff.

Sedimentary Rocks:

- The word 'sedimentary' is derived from the Latin word sedimentum which means settling.
- Rocks of the earth's surface are **exposed to denudational agents and are broken up** into various sizes of fragments.
- Such fragments **are transported by different exogenous agencies and deposited**. These **deposits** through compaction turn into **rocks**. This process is called **lithification**.
- There are number of layers of varying thickness in sedimentary rocks like sandstone, shale etc.
- They are classified based on the **mode of formation**:

- **Mechanically formed:** Sandstone, conglomerate, limestone, shale, loess etc.
- **Organically formed:** Geyserite, chalk, limestone, coal etc.
- **Chemically formed:** Chert, limestone, halite, potash etc.

Metamorphic Rocks:

- The word metamorphic means ‘**change of form**’. These rocks form under the action of **pressure, volume, and temperature (PVT)** changes.
- **Metamorphism** is a process by which **already consolidated rocks undergo recrystallisation and reorganisation** of materials within original rocks.
- Metamorphism occurs when rocks are forced down to lower levels by tectonic processes or when molten magma rising through the crust comes in contact with the crustal rocks or the underlying rocks are subjected to great amounts of pressure by overlying rocks.
- **Dynamic Metamorphism:** It is the **mechanical disruption and reorganisation** of the original minerals within rocks due to breaking and crushing without any appreciable chemical changes.
- **Thermal Metamorphism:** It cause the materials of rocks to chemically alter and recrystallise. It is of two types:
 - **Contact Metamorphism:** The rocks come in contact with hot intruding magma and lava and the rock materials **recrystallise under high temperatures**.
 - **Regional Metamorphism:** Rocks undergo recrystallisation **due to deformation** caused by tectonic shearing together with high temperature or pressure or both.
- In the process of metamorphism, some rock grains or **minerals get arranged in layers or lines**. Such an arrangement of minerals or grains in metamorphic rocks is called **foliation or lineation**.
- In metamorphic rocks, minerals and materials are **arranged in alternative thin to thick layers** which is called **banding** and rock displaying banding is called **banded rocks**.
- Metamorphic rocks are classified into two major groups - foliated and non-foliated rocks.
- **Examples:** Gneissoid, granite, syenite, slate, schist, marble and quartzite.
- **Rock cycle:** It is a continuous process through which **old rocks are transformed into new ones**.
- The crustal rocks (igneous, metamorphic and sedimentary) once formed may be carried down into the mantle (interior of the earth) **through subduction process**.
- The same **melt down due to increase in temperature** in the interior and turn into **molten magma**.

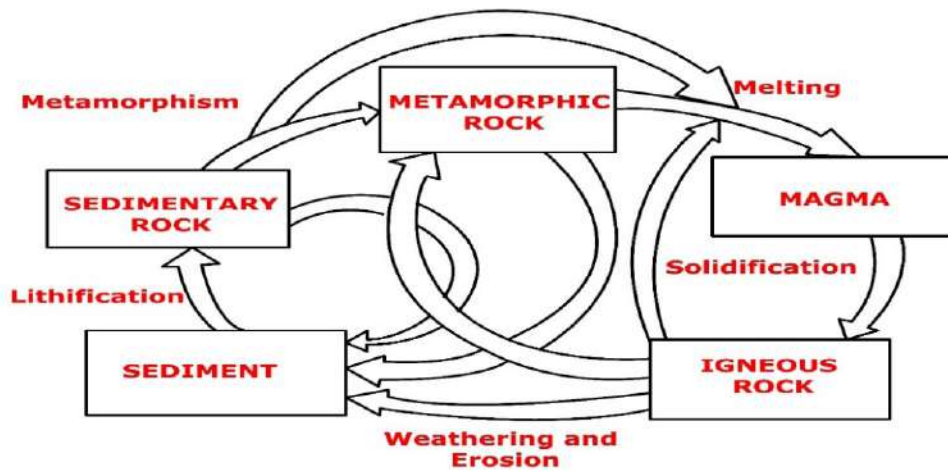


Fig: 5.1 Rock Cycle

Interesting Points:

- **Petrology** is science of **rocks**. A petrologist studies rocks in all their aspects viz., mineral composition,

texture, structure, origin, occurrence, alteration and relationship with other rocks.



6

Geomorphic Processes

The earth's crust is dynamic. The differences in the internal forces operating from within the earth which built up the crust have been responsible for the variations in the outer surface of the crust. The earth's surface is being continuously subjected to external forces induced basically by energy (sunlight).

Geomorphic Processes:

The **endogenic and exogenic forces** causing physical stresses and chemical actions on earth materials and bringing about **changes in the configuration of the surface** of the earth are known as **geomorphic processes**.

- Any exogenic element of nature (like water, ice, wind, etc.,) capable of acquiring and transporting earth materials can be called a **geomorphic agent** such as running water, glaciers, currents etc.
- When these elements of nature become mobile due to gradients, they remove the materials and transport them over slopes and deposit them at lower level.
- Geomorphic processes and geomorphic agents especially exogenic, unless stated separately, are one and the same.
- An **agent** is a mobile medium (like running water, moving ice masses, wind, waves and currents etc.) which removes, transports and deposits earth materials.

Importance of Gravity for geomorphic processes:

- Gravity besides being a **directional force activating all downslope movements**

of matter also causes stresses on the earth's materials.

- Indirect gravitational stresses activate wave and tide induced currents and winds.
- Without gravity and gradients there would be no mobility and hence no erosion, transportation and deposition are possible. So, gravitational stresses are as important as the other geomorphic processes.
- **Gravity is the force that switches on the movement** of all surface material on earth.
- **Gravitational force** applied **per unit area** is called **stress** which is produced in a solid by pushing or pulling induces deformation.
- **Forces acting along the faces** of earth materials are **shear stresses** (separating forces). This stress breaks rocks and other earth materials. It results in angular displacement or slippage.
- **Molecular stresses** may be caused by a number of factors amongst which temperature changes, crystallisation and melting are the most common.
- **Gradients:** All the movements either within the earth or on the surface of the earth occur due to gradients-from higher levels to lower levels, from high pressure to low pressure areas etc.

Forces Acting on Earth's Surface

Endogenic Forces:

- The internal forces are known as **endogenic forces**.
- These are mainly **land building forces**.
- They continuously elevate or build up parts of the earth's surface.

- **Diastrophism and volcanism** are endogenic geomorphic processes.

Exogenic Forces:

- The **external forces** are known as **exogenic forces**.
- The actions of exogenic forces result in **wearing down (degradation)** of relief/elevations and **filling up (aggradation)** of basins/ depressions, on the earth's surface.
- The phenomenon of **wearing down** of relief variations of the surface of the earth through erosion is known as **gradation**.
- **Weathering, mass wasting, erosion and deposition** are exogenic geomorphic processes.

Endogenic Processes:

- The **energy emanating within the earth** is the main force behind endogenic geomorphic processes. This energy is mostly generated by radioactivity, rotational and tidal friction and primordial heat from the origin of the earth.
- Due to variations in geothermal gradients and heat flow from within, crustal thickness and strength, the **action of endogenic forces are not uniform** and hence the tectonically controlled original crustal surface is uneven.

Diastrophism:

- All **processes that move, elevate or build up** portions of the earth's crust come under diastrophism. They include:
 - **Orogenic processes** involving mountain building through severe

folding and affecting long and narrow belts of the earth's crust.

- **Epeirogeny processes** involving uplift or warping of large parts of the earth's crust.
- **Earthquakes** involving local relatively minor movements.
- **Plate tectonics** involving horizontal movements of crustal plates.
- In the process of orogeny, the **crust is severely deformed into folds**.
- **Orogeny** is a **mountain building process** whereas **epeirogeny** is **continental building process**.
- Through the processes of orogeny, epeirogeny, earthquakes and plate tectonics, there can be **faulting and fracturing of the crust**.
- All these processes cause pressure, volume and temperature (PVT) changes which in turn induce metamorphism of rocks.

Volcanism:

Volcanism includes the **movement of molten rock** (magma) onto or toward the earth's surface and also formation of many intrusive and extrusive volcanic forms.

Exogenic Processes:

- The exogenic processes **derive their energy from atmosphere** determined by the **ultimate energy from the sun** and also the **gradients created by tectonic factors**.
- It acts upon all earth materials having a sloping surface and tend to produce movement of matter in down slope direction.

- **Chemical processes** normally **lead to loosening of bonds** between grains, dissolving of soluble minerals or cementing materials. Thus, the basic reason that leads to weathering, mass movements, and erosion is **development of stresses** in the body of the earth materials.
- **Temperature and precipitation** are the two important climatic elements that control various processes.
- All the exogenic geomorphic processes are covered under a general term, **denudation**. The word 'denude' means to strip off or to uncover.
- Weathering, mass wasting/movements, erosion and transportation are included in denudation.

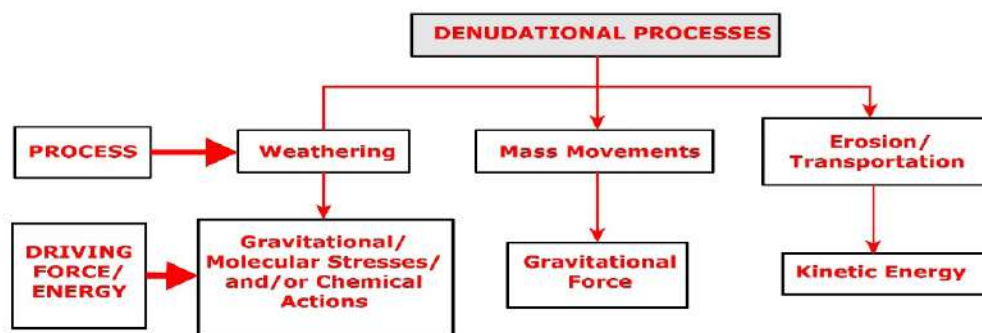


Fig. 6.1: Denudational process and their driving force.

- Within different climatic regions, there may be **local variations** of the effects of different climatic elements due to altitudinal differences, aspect variations and the variation in the amount of insolation received by north and south facing slopes as compared to east and west facing slopes.
- Further, due to differences in wind velocities and directions, amount and kind of precipitation, its intensity, the relation between precipitation and evaporation, daily range of temperature, freezing and thawing frequency, depth of frost penetration, the geomorphic processes vary within any climatic region.
- The **intensity of action of exogenic geomorphic processes depends upon type and structure of rocks**.
- The term structure includes such aspects of rocks as folds, faults, orientation and inclination of beds, presence or absence of joints, bedding planes, hardness or softness of constituent minerals, chemical susceptibility of mineral constituents; the permeability or impermeability.
- Different **types of rocks** with differences in their structure offer **varying resistances** to various geomorphic processes.
- A particular rock may be resistant to one process and non-resistant to another.

- Under varying climatic conditions, particular rocks may exhibit different degrees of resistance to geomorphic processes and hence they operate at differential rates and give rise to differences in topography.
- The effects of most of the **exogenic geomorphic processes** are small and slow and may be imperceptible in a **short time span**.

Various Exogenic Geomorphic Processes

Weathering:

- **Weathering** is defined as **mechanical disintegration and chemical decomposition of rocks** through the actions of various elements of weather and climate.
- Weathering is **action of elements of weather and climate** over earth materials. There are number of processes within weathering which act either individually or together to affect the earth materials in order to reduce them to fragmental state.
- As very little or no motion of materials takes place in weathering, it is an in-situ or on-site process.
- They are conditioned by many complex geological, climatic, topographic and vegetative factors. Climate is of particular importance.
- Not only weathering processes differ from climate to climate, but also the depth of the weathering mantle.

Types of Weathering Processes

Chemical Weathering Processes:

- A group of weathering processes viz; **solution, carbonation, hydration,**

oxidation and **reduction** act on the rocks to decompose, dissolve or reduce them to a fine clastic state through **chemical reactions** by oxygen, surface and/or soil water and other acids.

- **Water** and **air** (oxygen and carbon dioxide) along with **heat must be present** to speed up all chemical reactions.
- Over and above the carbon dioxide present in the air, decomposition of plants and animals increases the quantity of carbon dioxide underground.

Physical Weathering Processes:

- Physical or mechanical weathering processes depend on some **applied forces**.
- The applied forces could be:
 - **Gravitational forces:** Such as overburden pressure, load and shearing stress.
 - **Expansion forces:** Due to temperature changes, crystal growth or animal activity.
 - **Water pressures:** It is controlled by wetting and drying cycles.
- Most of the physical weathering processes are caused by **thermal expansion and pressure release**.
- They are small and slow but can cause great damage to the rock because of continued fatigue the rocks suffer due to repetition of contraction and expansion.

Biological Activity and Weathering:

- Biological weathering is contribution to or removal of minerals and ions from the weathering environment and physical changes **due to growth** or **movement of organisms**.

- **Burrowing and wedging** by organisms like earthworms, termites, rodents etc., help in exposing the new surfaces to chemical attack and assist in the penetration of moisture and air.
- **Human beings** by disturbing vegetation, ploughing and cultivating soils, also help in mixing and creating new contacts

between air, water and minerals in the earth materials.

- **Decaying plant and animal** matter help in the production of humic, carbonic and other acids which enhance decay and solubility of some elements.
- **Plant roots** mechanically break rocks by exerting great pressure.

Exfoliation:

- Exfoliation is not a process but it a **result of unloading, thermal contraction and expansion and salt weathering**.
- Exfoliation can occur **due to expansion and contraction** induced by temperature changes.
- Exfoliation domes and tors result due to unloading and thermal expansion, respectively.

Significance of the Weathering:

- Weathering processes are responsible for **breaking down the rocks** into smaller fragments and preparing the way for formation of not only regolith and soils, but also erosion and mass movements.
- **Biomes and biodiversity** are basically a result of forests (vegetation) and forests depend upon the depth of weathering mantles.
- Without weathering erosion is not significant as **weathering aids mass wasting, erosion and reduction** of relief and changes in landforms are a consequence of erosion.
- Weathering of rocks and deposits help in the **enrichment** and concentrations of **certain valuable ores** of iron, manganese, aluminium, copper etc.

Mass Movements:

- These movements transfer the **mass of rock debris down the slopes** under the

direct influence of **gravity**. It means air, water or ice do not carry debris with them from place to place but on the other hand the debris may carry with it air, water or ice.

- The movements of mass may range from **slow to rapid**, affecting shallow to deep columns of materials and include **creep, flow, slide and fall**.
- Gravity exerts its force on all matter, both bedrock and the products of weathering. So, **weathering** is not a pre-requisite for mass movement though it **aids mass movements**.
- Mass movements are **very active over weathered slopes**.
- Mass movements are **aided by gravity** and no geomorphic agent like running water, glaciers, wind, waves and currents participate in the process of mass movements.
- Mass movements do **not come under erosion** though there is a shift (aided by

gravity) of materials from one place to another.

- Materials over the slopes have their own resistance to disturbing forces and will yield only when force is greater than the shearing resistance of the materials.
- Weak unconsolidated materials, thinly bedded rocks, faults, steeply dipping beds, vertical cliffs or steep slopes, abundant precipitation and torrential rains and scarcity of vegetation etc., favour mass movements.

Activating causes of Mass Movements:

- **Removal of support** from below to materials above through natural or artificial means.
- **Increase in gradient** and height of slopes.
- **Overloading** through addition of materials naturally or by artificial filling.
- Overloading due to heavy rainfall, saturation and lubrication of slope materials.
- **Removal of material** or load from over the original slope surfaces.
- Occurrence of **earthquakes, explosions**.
- Excessive **natural seepage**.
- **Heavy drawdown of water** from lakes, reservoirs and rivers leading to slow outflow of water from under the slopes or riverbanks.
- Indiscriminate **removal of natural vegetation**.

Types of Movements:

- Heave (heaving up of soils due to frost growth and other causes)
- Flow
- Slide

Landslides:

- These are **relatively rapid and perceptible movements**.
- The materials involved are **relatively dry**.
- The size and shape of the detached mass depends on the nature of discontinuities in the rock, the degree of weathering and the steepness of the slope.

Types of Landslides based on types of movement:

- **Slump:** It is **slipping of one or several units of rock debris** with a **backward rotation** with respect to the slope over which the movement takes place.
- **Debris slide:** It is the **rapid rolling or sliding** of earth debris **without backward rotation** of mass.
- **Debris fall:** It is nearly a **free fall of earth debris** from a vertical or overhanging face.
- **Sliding:** Sliding of individual rock masses down bedding, joint or fault surfaces is **rockslide**. Over steep slopes, rock sliding is very fast and destructive.
- **Land slide:** Rock fall is **free falling of rock blocks** over any steep slope keeping itself away from the slope. Rock falls occur from the superficial layers of the rock face, an occurrence that distinguishes it from rockslide which affects materials up to a substantial depth.

Debris Avalanche and Landslide in India In the Himalayas:

- Himalayas are **tectonically active**.
- They are mostly made up of **sedimentary rocks** and **unconsolidated** and **semi-consolidated** deposits.

- The slopes are **very steep**.

In Western Ghats:

Compared to the Himalayas, the Nilgiris bordering Tamil Nadu, Karnataka, Kerala and the Western Ghats along the west coast are relatively **tectonically stable** and are mostly made up of very hard rocks; but still, debris avalanches and landslides occur.

- **Many slopes are steeper** with almost **vertical cliffs** and escarpments in the Western Ghats and the Nilgiris.
- **Mechanical weathering** due to **temperature changes** and ranges is pronounced.
- They receive **heavy amounts of rainfall** over short periods.

Erosion and Deposition:

Erosion involves **acquisition** and **transportation of rock debris** and erosional agents deposit transported material in plain areas.

- When **massive rocks break into smaller fragments** through weathering.
- Any other process, erosional geomorphic agents like running water, groundwater, glaciers, wind and waves **remove and transport** it to other places depending upon the dynamics of each of these agents.
- Abrasion by rock debris carried by these geomorphic agents also aids greatly in erosion.
- Weathering, mass-wasting and erosion are **degradational processes**.
- It is erosion that is largely responsible for continuous changes that the earth's surface is undergoing.

- The **denudational processes** like erosion and transportation are **controlled by kinetic energy**.

- The erosion and transportation of earth materials is brought about by wind, running water, glaciers, waves and ground water.

- Of these the first **three agents** are controlled by climatic conditions. They represent **three states of matter**, gaseous (wind), liquid (running water) and solid (glacier) respectively.

- The work of the other **two agents** of erosion (**waves and ground water**) is not controlled by climate.

- ◆ In case of **waves**, it is the **location** along the interface of litho and hydro sphere (coastal region) that will determine the work of waves.

- ◆ The work of **ground water** is **determined** more by the lithological character of the region. If the rocks are permeable and soluble and water is available only then **karst topography develops**.

- **Deposition** is a **consequence of erosion**.
- The erosional agents **lose their velocity** and hence energy on gentler slopes and the materials carried by them **start to settle** themselves.
- Deposition is **not actually the work of any agent**. The **coarser materials get deposited first** and finer ones later.
- By deposition depressions get filled up. The **same erosional agents** viz., running water, glaciers, wind, waves

and groundwater **act as aggradational or depositional agents** also.

Soil Formation:

- Soil is a **dynamic medium** in which many chemical, physical and biological activities go on constantly.
- Soil is a **result of decay** and is also the **medium for growth**.
- It may be alternatively cold and warm or dry and moist. Biological activity is slowed or stopped if the soil becomes too cold or too dry.
- Organic matter increases when leaves fall, or grasses die.

Process of Soil Formation:

- **Soil formation** or **pedogenesis** depends first on **weathering**. The weathering mantle (depth of the weathered material) which is the basic input for soil to form.
- The **weathered material** or transported deposits are **colonised by bacteria** and other inferior plant bodies like mosses and lichens and minor organisms take shelter in it.
- The dead remains of organisms and plants help in **humus accumulation**.
- Minor grasses and ferns may grow; later, bushes and trees will start growing through seeds brought in by birds and wind.
- Plant roots penetrate down, burrowing animals bring up particles, mass of material becomes porous and sponge-like with a capacity to retain water and to permit the passage of air and finally a **mature soil**, a **complex mixture of mineral and organic products forms**.

Soil Forming Factors:

- **Five basic factors** control the formation of soils: **parent material, topography, climate, biological activity, and time**.
- In fact, soil forming factors act in union and affect the action of one another.

Parent Material:

- Parent material is a **passive control factor** in soil formation.
- Parent materials can be any in-situ or on-site weathered rock debris (residual soils) or transported deposits (transported soils).
- Soil formation **depends upon the texture** (sizes of debris) **and structure** (disposition of individual grains/particles of debris) as well as the **mineral and chemical composition** of the rock debris/deposits.
- Nature and rate of the weathering and depth of weathering are important consideration under parent materials.
- When soils are very young and have not matured these show strong links with the type of parent rock.
- In limestone areas, where the weathering processes are specific and peculiar, soils will show clear relation with the parent rock.

Topography:

- Topography like parent materials is another **passive control factor**.
- The influence of topography is felt through the amount of exposure of a surface covered by parent materials to sunlight and the amount of surface and sub-surface drainage over and through the parent materials.

- Soils will be thin on steep slopes and thick over flat upland areas.
- **Over gentle slopes** where erosion is slow and **percolation of water is good, soil formation is very favourable.**
- **Soils over flat areas** may develop a **thick layer of clay** with good accumulation of **organic matter** giving the soil **dark colour.**

Climate:

Climate is an important **active factor** in soil formation. The climatic elements involved in soil development are:

- **Moisture:** Moisture in terms of its intensity, frequency and duration of precipitation - evaporation and humidity.
 - **Precipitation** gives soil its **moisture content** which makes the chemical and biological activities possible. Excess of water helps in the downward transportation of soil components through the soil (**eluviation**) and deposits the same down below (**illuviation**).
 - In climates like wet equatorial rainy areas with high rainfall, not only calcium, sodium, magnesium, potassium etc. but also a major part of silica is removed from the soil. **Removal of silica** from the **soil** is known as **desilication.**
 - In tropical climates and in areas with intermediate precipitation conditions, calcium carbonate nodules (*kanker*) are formed.
- **Temperature:** Temperature in terms of **seasonal and diurnal variations.**
 - Temperature acts in **two ways:** increasing or reducing chemical and biological activity.

- Chemical activity is increased in higher temperatures, reduced in cooler temperatures (with the exception of carbonation) and stops in freezing conditions.
- The tropical soils with higher temperatures show deeper profiles and in the frozen tundra regions soils contain largely mechanically broken materials.
- In **dry climates**, because of high temperature, evaporation exceeds precipitation and hence ground water is brought up to the surface by **capillary action** and in the process the water evaporates leaving behind salts in the soil. Such **salts form into a crust** in the soil known as **hardpans.**

Biological Activity:

- The vegetative cover and organisms that occupy the parent materials from the beginning and also at later stages help in adding organic matter, moisture retention, nitrogen etc.
- **Dead plants** provide **humus**, the finely divided organic matter of the soil.
- Some organic acids which form during humification aid in decomposing the minerals of the soil parent materials.
- Intensity of bacterial activity shows up differences between soils of cold and warm climates.
 - **Humus accumulates** in **cold climates** as bacterial growth is slow.
 - With undecomposed organic matter because of low bacterial activity, **layers of peat** develop in **subarctic and tundra climates.**

- In humid tropical and equatorial climates, **bacterial growth and action is intense** and dead vegetation is rapidly oxidised leaving very low humus content in the soil.
- **Nitrogen Fixation:**
 - Bacteria and other soil organisms take **gaseous nitrogen from the air** and **convert** it into a **chemical form** that can be used by plants. This process is known as **nitrogen fixation**.
 - **Rhizobium**, a type of bacteria, lives in the **root nodules of leguminous plants** and fixes nitrogen beneficial to the host plant.
- The influence of animals like ants, termites, earthworms, rodents etc. is mechanical, but it is nevertheless important in soil formation as they rework the soil up and down.
- In case of earthworms, as they feed on soil, the texture and chemistry of the soil that comes out of their body changes.

Time:

Time is the **third important passive controlling factor** in soil formation.

- The **length of time** the soil forming processes operate, determines maturation of soils and profile development.
- A soil becomes mature when all soil-forming processes act for a sufficiently long time developing a profile.
- Soils developing from **recently deposited alluvium or glacial till are considered young** and they **exhibit no horizons or only poorly developed horizons**.

Interesting Points:

- When rocks undergo weathering, some materials are removed through chemical or physical leaching by groundwater and thereby the concentration of remaining (valuable) materials increases.
- Without such a weathering taking place, the concentration of the same valuable material may not be sufficient and economically viable to exploit, process and refine. This is called **enrichment**.



7

Landforms and their Evolution

Several related landforms together make up landscapes, (large tracts of earth's surface). Each landform has its own physical shape, size, materials and is a result of the action of certain geomorphic processes and agents.

Landforms:

- It is a **small to medium sized part** of the surface of the earth.
- Landforms once formed **may change in their shape, size and nature** slowly or fast due to continued action of geomorphic processes and agents.
- Due to changes in climatic conditions and vertical or horizontal movements of landmasses, either the intensity of processes or the processes themselves might change leading to new modifications in the landforms.
- Every landform has a beginning and **passes through stages of development** e.g., youth, mature and old age.

Running Water:

- The running water is an important geomorphic agent in **humid regions** as it brings large scale degradation on land surfaces.
- **Two components of running water:**
 - **Overland flow** on general land surface as a sheet.
 - **Linear flow** as streams and rivers in valleys.
- **Types of Landforms:**
 - **Erosional Landforms:** Most of the erosional landforms made by running water are associated with **vigorous and youthful rivers** flowing over steep gradients. With time, stream

channels over steep gradients turn **gentler** due to **continued erosion**, and lose their velocity, facilitating active deposition.

- **Depositional Landforms:** These are associated with **streams flowing over steep slopes**. But these phenomena will be on a small scale compared to those associated with rivers flowing over medium to gentle slopes. The deposition will be greater in the gentler river in gradient or slope.
- When the stream beds turn gentler due to continued erosion, downward cutting becomes less dominant and lateral erosion of banks increases that led to the **hills and valleys** being **reduced to plains**.
- The minor or major quantities of materials from the surface of the land are removed **due to sheer friction** of the column of flowing water in the direction of flow and gradually **small and narrow rills** are formed.
- These rills will gradually develop into long and wide gullies which will further deepen, widen, lengthen, and unite to give rise to a **network of valleys**.
- In the **early stages**, **downcutting dominates** during which **irregularities** such as waterfalls and cascades will be **removed**.
- In the **middle stages**, streams **cut their beds slower**, and lateral erosion of valley sides becomes severe. Gradually, the **valley sides are reduced to lower** and lower slopes.
- The divides between drainage basins are lowered until they are almost completely flattened leaving finally a lowland of faint relief with some **low**

resistant remnants called **monadnocks** standing out here and there. This type of plain forming as a result of stream erosion is called a **peneplain (an almost plain)**.

Youth Stage:

- In this stage the **streams are few** with **poor integration** and flow over original slopes showing shallow **V-shaped valleys** with no floodplains or with very narrow floodplains.
- **Stream divides** are **broad and flat** with marshes, swamp and lakes.
- Meanders if present develop over broad upland surfaces and may entrench into uplands.
- Waterfalls and rapids may exist where local hard rock bodies are exposed.

Mature Stage:

- During this stage **streams are plenty** with good integration.
- The valleys are still **V-shaped** but **deep** and trunk streams are broad enough to have wider floodplains within which streams may flow in meanders confined within the valley.
- The **flat and broad inter stream areas** and swamps and marshes of youth **disappear** and the stream divides turn sharp.
- **Waterfalls** and rapids **disappear**.

Old Stage:

- **Smaller tributaries** during old age are **few** with gentle gradients.
- **Streams meander freely** over vast floodplains showing **natural levees, oxbow lakes**, etc.

- Divides are broad and flat with lakes, swamps, and marshes.
- Most of the **landscapes** is at or slightly **above sea level**.

Erosional Landforms (Running water)

Valleys:

- Valleys **start as small and narrow rills** that will gradually develop into long and wide gullies and the gullies will further deepen, widen, and lengthen to give rise to valleys.
- **Types of Valleys:** These are based on dimensions and shape such as V-shaped valley, gorge, canyon, etc.
 - **Gorge:** It is a **deep valley** with very **steep to straight sides** and is almost equal in width at its top as well as its bottom.
 - **Canyon:** It is characterised by **steep steplike side slopes** and may be as deep as a gorge. It is wider at its top than at its bottom. In fact, a **canyon is a variant of gorge**.
- Valley types depend upon the type and structure of rocks in which they form such as **canyons** commonly form in **horizontal bedded** sedimentary rocks and **gorges** form in **hard rocks**.

Potholes and Plunge Pools:

- **Potholes:** These are **more or less circular depressions** formed over the rocky beds of hill-streams because of **stream erosion** aided by the abrasion of rock fragments.
- Once a small and shallow depression forms, the pebbles and boulders get collected in small and shallow depressions and get rotated by flowing

water and consequently the **depressions grow in dimensions.**

- A series of such depressions eventually join, and the **stream valley gets deepened.**
- **Plunge Pools:** These are **large and deep holes** at the **base of waterfalls.** Large potholes are formed at the foot of the water falls because of the sheer impact of water and rotation of boulders.

Incised or Entrenched Meanders:

- Normally **erosion** is concentrated on the **bottom** of the stream channel in **streams** flowing rapidly over **steep gradients.**
- In the case of steep gradient streams, **lateral erosion** on the **sides of the valleys** is **not much** when compared to the streams flowing on low and gentle slopes.
- The streams flowing over gentle slopes, develop sinuous or meandering courses due to active lateral erosion.
- The **meandering courses** are commonly found over **floodplains** and delta plains where stream gradients are very gentle.
- **Incised or entrenched meanders:** These are very deep and wide meanders found cut in hard rocks.

River Terraces:

- River terraces are **surfaces** marking **old valley floor** or floodplain levels. They may be bedrock surfaces without any alluvial cover or alluvial terraces consisting of stream deposits.
- These are basically **products of erosion** as they result due to vertical erosion

by the stream into its own depositional floodplain.

- There can be number of such terraces at different heights indicating former river-bed levels.
- **Paired Terraces:** These are river terraces which may occur at the same elevation on either side of the rivers.

Depositional Landforms (Running water)

Alluvial Fans:

- These are formed when **streams** flowing from **higher levels break into foot slope** plains of low gradient.
- Normally very coarse load is carried by streams flowing over mountain slopes. This load becomes too heavy for the streams to be carried over gentler gradients and gets dumped and spread as a **broad low to high cone shaped deposit** called **alluvial fan.**
- The streams which flow over fans are not confined to their original channels for long and **shift their position** across the fan forming many channels called **distributaries.**
- Alluvial fans in **humid areas** show normally **low cones with gentle slope** from head to toe and in **arid and semi-arid climates**, they appear as **high cones with steep slope.**

Deltas:

- Deltas are like alluvial fans but **develop** at a **different location.**
- The load carried by the rivers is dumped and spread into the sea. If this load is not carried away far into the sea or distributed along the coast,

it spreads and accumulates as a low cone.

- Unlike in alluvial fans, the deposits making up deltas are very **well sorted with clear stratification**.
- The **coarsest materials** settle out **first** and the **finer fractions** like silts and clays are carried out into the **sea**.
- As the **delta grows**, the **river distributaries** continue to **increase in length** and delta continues to build up into the sea.

Flood plains:

- Floodplain is a major landform of **river deposition**. Large sized materials are deposited first when stream channel breaks into a gentle slope.
- **Fine sized materials like sand, silt and clay** are carried by relatively slow-moving waters in gentler channels **usually found in the plains and deposited over the bed** and when the waters spill over the banks during flooding above the bed.
- The floodplain above the bank is **inactive floodplain**. It basically contains two types of deposits: **flood deposits** and **channel deposits**.
- In **plains, channels shift laterally** and change their courses occasionally leaving cut-off courses which get filled up gradually. Such areas over flood plains built up by abandoned or cut-off channels contain coarse deposits.
- The flood deposits of spilled waters carry relatively finer materials like silt and clay.
- The flood plains in a delta are called **delta plains**.

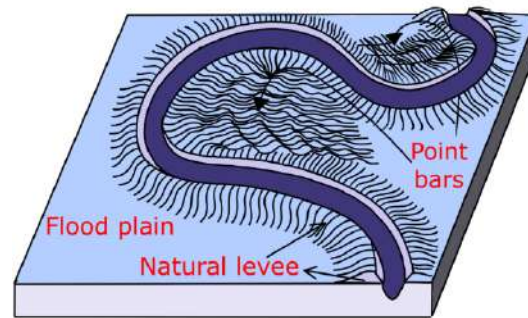


Fig. 7.1.: Natural Levees and Point Bars:

Natural Levees and Point Bars:

- These are landforms **associated with floodplains**.
- **Natural levees** are found **along the banks** of large rivers. They are low, linear, and parallel ridges of coarse deposits along the banks of rivers, quite often cut into individual mounds.
- **Point bars** are also known as **meander bars**. They are found on the **concave side of meanders** of large rivers and are sediments deposited in a linear fashion by flowing waters along the bank. They are almost uniform in profile and in width and contain mixed sizes of sediments.

Meanders:

- In large flood and delta plains, rivers rarely flow in straight courses. **Loop-like channel patterns** called **meanders** develop over flood and delta plains.
- It is **not a landform** but is only a type of **channel pattern** because of:
 - **Propensity of water** flowing over very gentle gradients to work laterally on the banks.
 - Unconsolidated nature of **alluvial deposits** making up the banks with

many irregularities which can be used by water exerting pressure laterally.

- **Coriolis force** acting on the fluid water deflecting it like it deflects the wind.
- Slight irregularities along the banks slowly get transformed into a small curvature in the banks.
- The curvature deepens due to deposition on the inside of the curve and erosion along the bank on the outside.

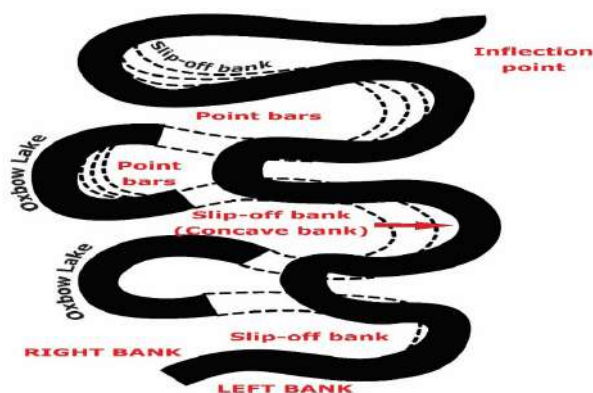


Fig. 7.2: Meander growth and cut-off loops and Slip-off and undercut banks

- If there is no deposition and no erosion or undercutting, the **tendency to meander is reduced**.
- In meanders of large rivers, there is active deposition along the concave bank and undercutting along the convex bank.
 - The **concave bank** is known as **cut-off bank** which shows up as a steep scarp.
 - The **convex bank** presents a long, gentle profile.
- As **meanders** grow into deep loops, the

same may get **cut-off due to erosion** at the inflection points and are left as **ox-bow lakes**.

Work of Groundwater:

- The **surface water percolates** well in permeable, thinly bedded and highly jointed and cracked rocks.
- After vertically going down to some depth, the **water** under the **ground flows horizontally** through the bedding planes, joints or through the materials themselves.
- **Physical or mechanical removal** of materials by moving groundwater is **insignificant** in developing landforms and hence the results of the work of groundwater cannot be seen in all types of rocks.
- **In rocks like limestones or dolomites** rich in calcium carbonate, the surface water as well as groundwater through the **chemical process** of solution and precipitation deposition develop varieties of landforms.
- **Karst Topography:** It is any **limestone or dolomitic region** showing typical landforms produced by the **action of groundwater** through the processes of **solution and deposition**. This is after the typical topography developed in limestone rocks of Karst region in the Balkans adjacent to Adriatic Sea.

Erosional Landforms (Karst Topography) Pools, Sinkholes, Lapies and Limestone Pavements:

- Small to medium sized round to sub-rounded shallow depressions called **swallow holes** form on the surface of limestones through solution.

- **Sinkhole:** It is an **opening more or less circular** at the top and funnel-shaped towards the bottom with sizes varying in area from a few sq. m to a hectare.
- Some of these form solely through solution action (solution sinks) and others might start as solution forms first and if the bottom of a sinkhole forms the roof of a void or cave underground, it might collapse leaving a large hole opening into a cave or a void below (**collapse sinks**). The **Doline** is sometimes used to refer the collapse sinks.
- **Solution sinks are more common than collapse sinks.** The surface runoff simply goes down swallow and sink holes and flow as underground streams and re-emerge at a distance downstream through a cave opening.
- When sink holes and dolines join together because of slumping of materials along their margins or due to roof collapse of caves, long, **narrow to wide trenches** called **valley sinks or Uvalas** form.
- Gradually, most of the surface of the limestone is eaten away by pits and trenches, leaving it extremely irregular with a maze of points, **grooves, and ridges or lapies**.
- **Limestone Pavements:** The **lapie field** may eventually turn into somewhat **smooth**.

Caves:

- The caves formation is prominent in areas where there are **alternating beds of rocks** (shales, sandstones, quartzites) with limestones or dolomites in between or in areas where limestones are dense, massive and occurring as thick beds.
- Water percolates down either through the materials or through cracks and joints and moves horizontally along bedding planes.
- **Caves:** These are long and narrow to wide gaps formed when the limestone get dissolved along bedding planes. Caves normally have an opening through which cave streams are discharged.
- **Tunnels:** These are **caves** having **openings at both the ends**.

Depositional Landforms by Groundwater:

- The **chief chemical** in limestone is **calcium carbonate** which is easily soluble in carbonated water (carbon dioxide absorbed rainwater).
- This calcium carbonate is deposited when the water carrying it in solution evaporates or loses its carbon dioxide as it trickles over rough rock surfaces.

Stalactites, Stalagmites and Pillars:

- **Stalactites:** They **hang as icicles** of different diameters. Normally they are broad at their bases and taper towards the free ends showing up in a variety of forms.
- **Stalagmites:** They **rise up** from the floor of the caves and form due to dripping water from the surface or through the thin pipe, of the stalactite, immediately below it. They may take the **shape of a column, a disc**, with either a smooth, rounded bulging end or a miniature crater like depression.
- The stalagmite and stalactites eventually fuse to give rise to **columns** and **pillars** of different diameters.

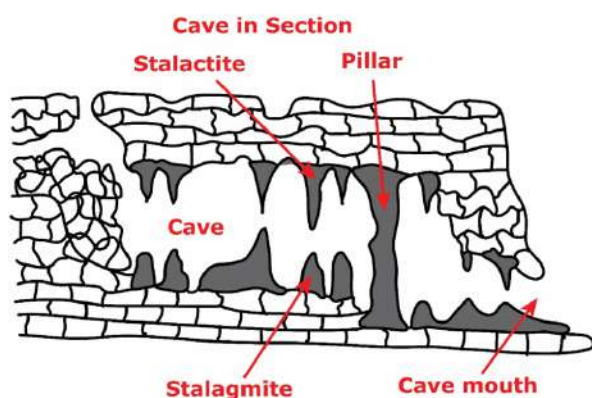


Fig. 7.3: Caves

Glaciers:

- **Masses of ice** moving as **sheets** over the land (continental glacier or piedmont glacier if a vast sheet of ice is spread over the plains at the foot of mountains) or as **linear flows** down the slopes of mountains in broad trough-like valleys (mountain and valley glaciers) are called **glaciers**.
- Their **movement** is slow and is because of the **force of gravity**.
- Their **erosion is tremendous** because of **friction** caused by **sheer weight** of the ice.
- The **material plucked** from the land by glaciers (usually large-sized angular blocks and fragments) get dragged along the floors or sides of the valleys and **cause great damage through abrasion and plucking**.
- Glaciers can cause significant damage to even un-weathered rocks and can reduce high mountains into low hills and plains.

Erosional landforms formed by glaciers:**Cirque:**

- Cirques are found on heads of the glacial valleys. They are **deep, long, and wide troughs** or **basins** with very steep concave to vertically dropping high walls at its head as well as sides.
- A lake of water can be seen quite often within the cirques after the glacier disappears. Such lakes are called **cirque** or **tarn lakes**.

Horns and Serrated Ridges:

- **Horns:** These are high, sharp pointed and steep sided peaks formed if **three or more** radiating **glaciers cut headward** until their cirques meet.
- The divides between cirque side walls or head walls get narrow because of progressive erosion and turn into **serrated or saw-toothed ridges** sometimes referred to as **arêtes** with very sharp crest and a zig-zag outline.

Glacial Valleys/ Troughs:

- **Glaciated valleys:** These are **trough-like** and **U-shaped** with broad floors and relatively smooth, and steep sides.
- The valleys may contain littered debris or debris shaped as moraines with swampy appearance.
- There can be **hanging valleys** at an elevation on one or both sides of the main glacial valley.
- The faces of divides or spurs of such hanging valleys opening into main glacial valleys are quite often truncated to give

them an appearance like **triangular facets**.

- Very deep glacial troughs filled with sea water and making up shorelines (in high latitudes) are called **fjords/fiords**.

Depositional Landforms Formed by Glaciers:

Glacial Till:

These are unassorted coarse and fine debris dropped by the melting glaciers. Most rock fragments in till are angular to sub angular in form.

Outwash Deposit:

These are glacio-fluvial deposits which are rock debris small enough to be carried by melt water stream. The rock fragments are rounded at their edges. Unlike till deposits, the **outwash deposits** are **roughly stratified** and assorted.

Moraines:

- They are **long ridges** of deposits of glacial till.
- **Terminal Moraines:** These are long ridges of debris and deposited **at the end (toe) of the glaciers**.
- **Lateral Moraines:** They may **join a terminal moraine** forming a horse-shoe shaped ridge. These moraines partly or fully owe their origin to glacio-fluvial waters pushing up materials to the sides of glaciers.
- **Ground Moraines:** Many valley glaciers retreating rapidly leave an **irregular sheet of till** over their valley floors. Such deposits varying greatly in thickness and in surface topography are called ground moraines.

- **Medial Moraines:** These are moraine in the **centre of the glacial valley** flanked by lateral moraines. They are imperfectly formed as compared to lateral moraines. Sometimes These are indistinguishable from ground moraines.

Eskers:

- When glaciers melt in summer, the water flows on the surface of the ice or seeps down along the margins or even moves through holes in the ice.
- These waters accumulate beneath the glacier and flow like streams in a channel beneath the ice.
- Such **streams flow over the ground** (not in a valley cut in the ground) with ice forming its banks.
- Very coarse materials like boulders and blocks along with some minor fractions of rock debris carried into this stream settle in the valley of ice beneath the glacier and after the ice melts can be found as a **sinuous ridge** called **esker**.

Outwash Plains:

- The plains at the foot of the glacial mountains or beyond the limits of continental ice sheets are covered with **glacio-fluvial deposits**.
- It is in the form of broad flat alluvial fans which may **join** to form **outwash plains** of gravel, silt, sand and clay.

Drumlins:

- **Drumlins:** They are smooth **oval shaped ridge-like features** composed mainly of **glacial till** with some masses of gravel and sand.
- The **long axes of drumlins are parallel to the direction of ice movement**.

- They may measure up to 1 km in length and 30 m or so in height.
- One **end** of the drumlins **facing the glacier** called the **stoss end** is blunter and **steeper than** the other end called **tail**.
- The drumlins form due to dumping of rock debris beneath heavily loaded ice through fissures in the glacier.
- The stoss end gets blunted due to pushing by moving ice.
- **Drumlins give an indication of direction of glacier movement.**

Waves and Currents:

Coastal processes are the most dynamic and hence most destructive. There can be erosion in one season and deposition in another. Most of the changes along the coasts are accomplished by waves.

- Constant impact of **breaking waves** drastically **affects the coasts**.
- **Storm waves and tsunami waves** can cause far-reaching changes in a short period of time than normal breaking waves.
- Apart from the action of waves, the **coastal landforms depend upon**:
 - The configuration of land and sea floor.
 - Whether the coast is **advancing (emerging)** seaward or **retreating (submerging)** landward.
- Assuming sea level to be constant, **two types of coasts** are considered to explain the concept of evolution of coastal landforms:
 - **Submerged coasts:** High, rocky coasts.
 - **Emerged coasts:** Low, smooth and gently sloping sedimentary coasts.

High Rocky Coasts:

- Along the high rocky coasts, the **rivers** appear to have been **drowned with highly irregular coastline**.
- The coastline appears highly indented with extension of water into the land where **glacial valleys (fjords)** are present.
- The hill sides drop off sharply into the water.
- Shores do not show any depositional landforms initially and erosion features dominate.
- Along high rocky coasts, waves break with great force against the land shaping the hill sides into cliffs.
- With constant pounding by waves, the cliffs recede leaving a **wave-cut platform** in front of the sea cliff.
- Waves gradually minimise the irregularities along the shore.
- The materials which fall off, and removed from the sea cliffs, gradually break into smaller fragments, and roll to roundness, will get deposited in the offshore.
- After a considerable period of cliff development and retreat when coastline turns somewhat smooth, with the addition of some more material to this deposit in the offshore, a wave-built terrace would develop in front of **wave-cut terrace**.
- Bars are long ridges of sand and/ or shingle parallel to the coast and are **submerged features**.
- When **bars show up above water**, they are called **barrier bars**.
- **Spit:** It is a **barrier bar** which gets **keyed up to the headland** of a bay.

- **Lagoon:** It is formed when barrier bars and spits form at the mouth of a bay and block. It would gradually get filled up by sediments from the land giving rise to a coastal plain.

Low Sedimentary Coasts:

- Along low sedimentary coasts the rivers appear to extend their length by building coastal plains and deltas.
- The **coastline** appears **smooth** with occasional incursions of water in the form of lagoons and tidal creeks.
- The land slopes gently into the water and marshes and swamps may abound along the coasts.
- Depositional features dominate.
- When waves break over a gently sloping sedimentary coast, the bottom sediments get churned and move readily **building bars, barrier bars, spits and lagoons**.
- **Lagoons** would eventually turn into a **swamp** which would subsequently turn into **a coastal plain**.
- The maintenance of these depositional features depends upon the steady supply of materials.
- Storm and tsunami waves cause drastic changes irrespective of supply of sediments.
- Large rivers which bring lots of sediments **build deltas** along low sedimentary coasts.

Erosional Landforms formed by Waves

Cliffs, Terraces, Caves and Stacks:

- **Wave-cut cliffs and terraces** are two forms usually found where erosion is the dominant shore process.

- At the foot of sea cliffs there may be a flat or gently sloping platform covered by rock debris derived from the sea cliff behind. Such **platforms** occurring at **elevations** above the average height of waves is called a **wavecut terrace**.
- The **lashing of waves** against the base of the cliff and the rock debris that gets smashed against the cliff along with lashing waves **create hollows** and these hollows get **widened and deepened** to form **sea caves**.
- Retreat of the cliff may leave some remnants of rock standing isolated as small islands just off the shore. Such resistant masses of rock, originally parts of a cliff or hill are called **sea stacks**.
- Sea stacks are also **temporary** and eventually **coastal hills and cliffs will disappear** because of wave erosion giving rise to narrow coastal plains.

Depositional Landforms Formed by Waves

Beaches:

- Beaches are characteristic of **shorelines** that are **dominated by deposition** but may occur as patches along even the rugged shores.
- Most of the **sediment** making up the beaches comes from land **carried by the streams** and rivers or from wave erosion. Beaches are temporary features.
- The sandy beach which appears so permanent may be reduced to a very narrow strip of coarse pebbles in some other season.
- Beaches called **shingle beaches** contain excessively small pebbles and even cobbles.

Dunes:

- Just behind the beach, the **sands lifted** and winnowed from **over the beach surfaces** will be deposited as **sand dunes**.
- Sand dunes forming long ridges parallel to the coastline are very common along low sedimentary coasts.

Bars, Barriers and Spits:

- A **ridge of sand** and shingle formed in the sea in the **off-shore zone** (from the position of low tide waterline to seaward) **lying** approximately **parallel to the coast** is called an **off-shore bar**.
- An offshore bar which is exposed due to further addition of sand is termed a **barrier bar**.
- The offshore bars and barriers commonly form across the mouth of a river or at the entrance of a bay.
- The **barrier bars** which is **attached from one end** to the coast is called **spit**.
- The barriers, bars and spits at the mouth of the bay **gradually extend** leaving only a **small opening** of the bay into the sea and the bay will eventually develop into a **lagoon**.
- The lagoons later filled by sand brought by wind and broad wide plain develop replacing lagoon.

Winds:

- Wind is one of the two dominant agents in **hot deserts**.
- The heated floors heat up the air directly above them and result in upward movements in the hot lighter air with turbulence, and any obstructions in its path sets up **eddies, whirlwinds, updrafts** and **downdrafts**.

- Winds also move along the desert floors with great speed and the obstructions in their path **create turbulence**.
- Wind causes **deflation, abrasion and impact**.
- **Deflation** includes **lifting and removal of dust** and smaller particles from the surface of rocks. this sand blasting operations of the wind give rise to the various landforms.
- In fact, many features of deserts owe their formation to mass wasting and running water as **sheet floods**.
- The **desert** rocks **devoid of vegetation**, exposed to **mechanical and chemical weathering** processes due to **drastic diurnal temperature changes**, decay faster and the torrential rains help in removing the weathered materials easily.
- Debris in deserts is not only moved by winds but also by rain/sheet wash.
- The wind moves fine materials and general mass erosion is accomplished mainly through sheet floods or sheet wash.
- **Stream channels** in desert areas are broad, smooth and indefinite and flow for a brief time after rains.

Erosional Landforms in Deserts**Pediments and Pediplains:**

- **Pediments:** These are gently **inclined rocky floors** close to the mountains at their foot with or without a thin cover of debris. These are formed through the **erosion of mountain front** through a combination of lateral erosion by streams and sheet flooding.
- Once, pediments are formed with a steep wash slope followed by cliff or

free face above it, the steep wash slope and free face retreat backwards. This method of erosion is termed as **parallel retreat of slopes** through **backwasting**.

- Through parallel retreat of slopes, the pediments extend backwards at the expense of mountain front, and gradually, the mountain gets reduced leaving **an inselberg** which is a remnant of the mountain.
- The high relief in desert areas is reduced to low featureless plains called **pediplains**.

Playas:

- In basins with mountains and hills around and along, the drainage is towards the centre of the basin and due to gradual deposition of sediment from basin margins, a nearly level plain forms at the centre of the basin.
- In times of sufficient water, this plain is covered up by a shallow water body. Such types of **shallow lakes** are called as **playas** where **water is retained** only for a **short duration** due to evaporation and quite often the playas contain good deposition of salts.
- **Alkali Flats:** These are the playa plain covered up by **salts**.

Deflation Hollows and Caves:

- **Weathered mantle** from over the rocks or bare soil, **gets blown** out by persistent movement of wind currents in one direction. This process may **create shallow depressions** called **deflation hollows**.
- **Deflation** also creates numerous small pits or cavities over rock surfaces. The rock faces suffer impact and abrasion

of wind-borne sand and first shallow depressions called **blow outs** are created.

- Some of the **blow outs** become **deeper and wider** to be called **caves**.

Mushroom, Table, and Pedestal Rocks:

- Many **rock-outcrops** in the deserts easily **susceptible** to wind deflation and abrasion are worn out quickly leaving some remnants of resistant rocks polished beautifully in the **shape of mushroom** with a slender stalk and a broad and rounded pear-shaped cap above.
- The top surface is broad like a **table-top** and quite often, the **remnants** stand out like **pedestals**.

Depositional Landforms in Deserts:

- Wind is a **good sorting agent**. Depending upon the velocity of wind, different sizes of grains are moved along the floors **by rolling or saltation** and carried in **suspension** and in this process of transportation itself, the materials get sorted.
- When the wind slows or begins to die down, depending upon sizes of grains and their critical velocities, the grains will begin to settle. So, good sorting of grains can be found in depositional landforms.

Sand Dunes: **Dry hot deserts** are good places for sand dune formation. Obstacles to initiate dune formation are equally important. There can be a great variety of dune forms:

- **Barchans:** These are **crescent shaped dunes** with the points or wings directed away from wind direction i.e., downwind,

form where the wind direction is constant and moderate and where the original surface over which sand is moving is almost uniform.

- **Parabolic Dunes:** They form when **sandy surfaces** are **partially covered** with vegetation. These are **reversed barchans** with wind direction being the same.
- **Seif:** It is similar to barchan with a small difference that it has **only one wing or point** due to shift in wind conditions. The lone wings of **seifs** can grow very long and high.

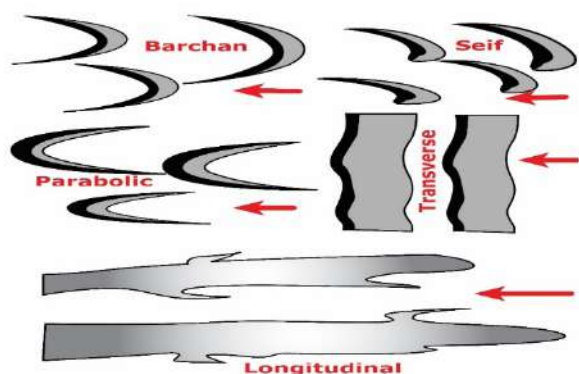


Fig. 7.4: Various types of Sand Dunes Arrows indicate Wind Direction

- **Longitudinal Dunes:** They form when **supply of sand is poor** and wind direction is constant. They appear as **long ridges** of considerable length but low in height.
- **Transverse Dunes:** They are aligned **perpendicular to wind direction**. These dunes form when the wind direction is

constant, and the source of sand is an elongated feature at right angles to the wind direction. They may be very long and low in height.

- When sand is plenty, the regular shaped dunes coalesce and lose their individual characteristics.
- Most of the dunes in the deserts shift and a few of them will get stabilised especially near human habitations.

Interesting Points:

- **Bhagirathi** river is basically fed by meltwaters from under the snout (Gaumukh) of the **Gangotri glacier**. **Alkapuri glacier** feeds waters to **Alakananda river**.
- Rivers **Alkananda** and **Bhagirathi join** to make river **Ganga** near **Devprayag**.
- The highest peak in the **Alps, Matterhorn** and the highest peak in the **Himalayas, Everest** are **horns** formed through headward erosion of radiating cirques.
- The **west coast** of India is a **high rocky retreating coast** and is dominated by **erosional forms**. The **east coast** of India is a **low sedimentary coast** and dominated by **depositional forms**.
- The **coastal offshore bars** offer the first **buffer or defence** against storm or tsunami by absorbing most of their destructive force. Then come the **barriers, beaches, beach dunes and mangroves** are also offer defence against these forces.



Unit IV: Climate



8

Composition and Structure of the Atmosphere

Atmosphere is a mixture of different gases and it envelopes the Earth all round. The air is an integral part of the earth's mass and **99 per cent of the total mass of the atmosphere is confined to the height of 32 km** from the earth's surface.

Composition of the Atmosphere:

- The atmosphere is composed of **gases, water vapour** and **dust particles**.
- The gases proportion changes in the **higher layers** of the atmosphere in such a way that **oxygen** will be almost in **negligible** quantity at the height of 120 km.
- The **carbon dioxide and water vapour** are found **only up to 90 km** from the surface of the earth.

Gases:

- **Carbon dioxide:** It is meteorologically a very important gas as it is **transparent** to the **incoming solar radiation** but **opaque** to the **outgoing terrestrial radiation**. It absorbs some part of terrestrial radiation and reflect back some of it. It is largely responsible for **green-house gas effect**.
- The volume of carbon dioxide has been rising in the past few decades mainly because of the burning of fossil fuels and subsequently it has **increased temperature of the gases**.
- **Ozone:** It is found between **10 and 50 km** above the earth's surface and acts as a **filter** and **absorbs the ultra-violet rays** radiating from the sun and prevents them from reaching the surface of the earth.

Water Vapour:

- It is also a **variable gas** in the atmosphere which decreases with altitude.
- In the **warm and wet tropics**, it may account for **four per cent** of the air by volume, while in the **dry and cold areas**, it may be **less than one per cent** of the air.
- It **decreases** from the **equator towards the poles**.
- It also absorbs parts of the insolation from the sun and preserves the earth's radiated heat. It acts like a **blanket** allowing the earth neither to become too cold nor become too hot.

Dust Particle:

- Atmosphere has a sufficient capacity to keep **small solid particles** which may originate from different sources and includes sea salts, fine soil, smoke-soot, ash, pollen, dust and disintegrated particles of meteors.
- They are generally concentrated in the **lower layers of the atmosphere**. Yet, convectional air currents may transport them to great heights.
- It has **higher concentration** in **subtropical and temperate regions** due to dry winds in comparison to equatorial and polar regions.
- **Dust and salt particles** act as **hygroscopic nuclei** around which water vapour condenses to **produce clouds**.

Structure of the Atmosphere:

- The atmosphere consists of different layers with varying density and temperature.

- **Density decreases with increasing altitude** and is highest near the surface of the earth.
- The column of atmosphere is divided into **five different layers** depending upon the **temperature condition**.

Troposphere:

- The troposphere is the **lowermost layer** of the atmosphere.
- Its average height is 13 km and extends roughly to a height **of 8 km near the poles and about 18 km at the equator**.
- **Thickness** of the troposphere is **greatest at the equator** because heat is transported to great heights by strong convectional currents.
- This layer **contains dust particles and water vapour**. All changes in climate and weather take place in this layer.
- The **temperature** in this layer **decreases at the rate of 1° C for every 165m** of height.
- This is the most **important layer** for all **biological activity**.
- **Tropopause:** It is the zone **separating the troposphere from stratosphere**. The air temperature at the tropopause is about minus 80°C over the equator and about minus 45°C over the poles. It is called **tropopause** as the **temperature in tropopause is nearly constant**.

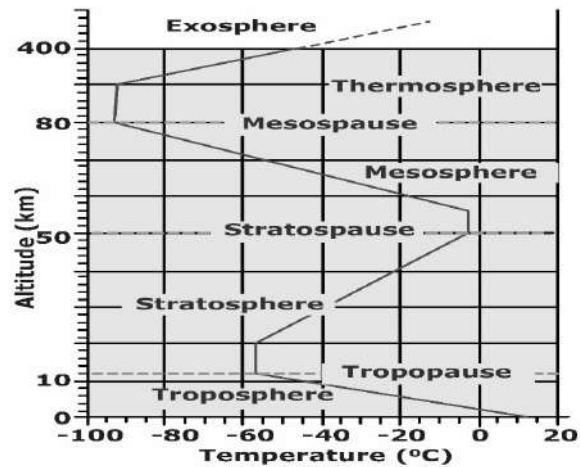


Fig. 8.1: Structure of atmosphere

Stratosphere:

- It is found **above the tropopause** and extends up to a height of 50 km.
- It contains the **ozone layer** which **absorbs ultra-violet radiation** and shields life on the earth from intense, harmful form of energy.

Mesosphere:

- It lies **above the stratosphere**, which extends up to a height of 80 km.
- In this layer **temperature starts decreasing with the increase in altitude** and reaches up to minus 100° C at the height of 80 km.
- **Mesopause:** It is the **upper limit of mesosphere**.

Ionosphere:

- It is located between 80 and 400 km **above the mesopause**.
- It contains **electrically charged particles** known as **ions**, and hence, it is known as **ionosphere**.



- It **reflects back the radio waves** transmitted from the earth.
- In this layer, **temperature starts increasing** with height.

Exosphere:

- It is the **uppermost layer** of the atmosphere **above the thermosphere**.
- It is the **highest layer** but very little is known about it.
- The contents in this layer are **extremely rarefied** and it gradually **merges with the outer space**.

The main elements of atmosphere which are subject to change and which influence human life on earth are temperature, pressure, winds, humidity, clouds and precipitation.

Interesting Points:

- The air is **colourless and odourless** and can be felt only when it blows as wind.

The earth receives almost all of its energy from the sun. The earth in turn radiates back to space the energy received from the sun. The amount of heat received by different parts of the earth is not the same which causes pressure differences in the atmosphere. This leads to the transfer of the heat from one region to other region by wind.

Solar Radiation:

- The **earth's surface receives** most of its energy in **short wavelengths**.
- The **energy received** by the earth is known as **incoming solar radiation** which in short is termed as **insolation**.
- As the earth is a **geoid** resembling a sphere, the **sun's rays fall obliquely** at the top of the atmosphere and the earth intercepts a very small portion of the sun's energy.
- On an average the earth receives **1.94 calories per sq. cm per minute** at the top of its atmosphere.
- The solar output varies slightly in a year due to the variations in the distance between the earth and the sun.
- **Aphelion:** It is the position of the earth when during its revolution around the sun, it is **farthest** from the sun (152 million km) on **4th July**.
- **Perihelion:** On **3rd January**, the earth is the **nearest to the sun** (147 million km). The annual insolation received by the earth on 3rd January is slightly more than the amount received on 4th July.
- The effect of this variation in the solar output is masked by other factors like

the distribution of land and sea and the atmospheric circulation.

- This variation in the solar output does not have great effect on daily weather.

Variation of Insolation at the Surface of the Earth:

- The amount and the intensity of insolation **vary** during a day, in a season and in a year.
- **Various factors causing variations in Insolation:**
 - The rotation of earth on its axis.
 - The angle of inclination of the sun's rays.
 - The length of the day.
 - The transparency of the atmosphere.
 - The configuration of land in terms of its aspect.
- The **earth's axis** makes an angle of **66½°** with the plane of its orbit round the sun has a greater **influence** on the **amount of insolation** received at **different latitudes**.
- The **second factor** that determines the amount of insolation received is the angle of inclination of the rays which depends on the latitude of a place.
- The **higher the latitude the less is the angle** they make with the surface of the earth resulting in slant sun rays. The **area covered by vertical rays is always less than the slant rays**.
- If **more area is covered**, the **energy gets distributed** and the net energy received per unit area decreases.
- The slant rays are required to pass through greater depth of the atmosphere resulting in more absorption, scattering and diffusion.

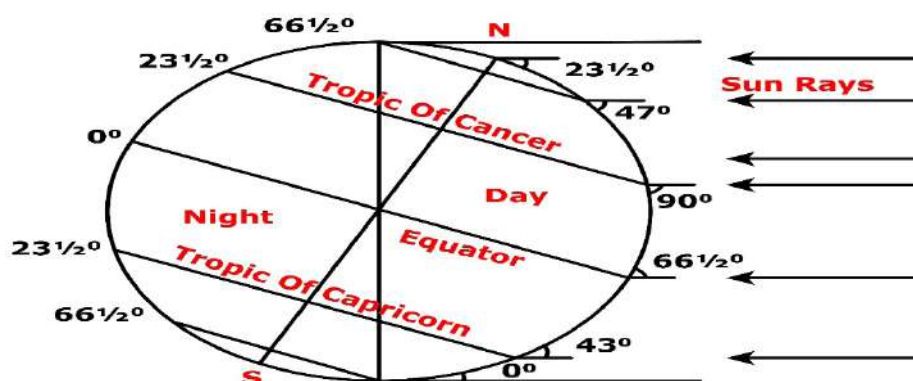


Fig. 9.1: Summer Solstice

Passage of the Solar Radiation through the Atmosphere:

- The atmosphere is largely **transparent to short wave solar radiation** (incoming solar radiation).
- Within the **troposphere** water vapour, ozone and other gases **absorb** much of the **near infrared radiation**.
- The very **small-suspended particles** in the troposphere **scatter** visible spectrum both to the space and towards the earth surface which adds **colour to the sky**.
- The **red colour of the rising and the setting sun** and the **blue colour of the sky** are the result of **scattering of light** within the atmosphere.

Spatial Distribution of Insolation at the Earth's Surface:

- The insolation received at the surface varies from about 320 Watt/m² in the tropics to about 70 Watt/m² in the poles.
- The **subtropical deserts** receive **maximum insolation** where the cloudiness is the least.

- **Equator** receives comparatively **less insolation** than the tropics.
- At the **same latitude**, the **insolation** is **more over the continent** than over the oceans.
- **In winter**, the **middle and higher latitudes** receive **less radiation** than in summer.

Heating and Cooling of the Atmosphere:

There are different ways of heating and cooling of the atmosphere.

- The earth after being heated by insolation transmits the heat to the atmospheric layers near to the earth in long wave form.
- **Conduction:**
 - It is the process when the **air in contact with the land gets heated slowly** and the upper layers in contact with the lower layers also get heated.
 - It takes place when **two bodies of unequal temperature** are in contact with one another, there is a **flow of energy** from the warmer to cooler body.

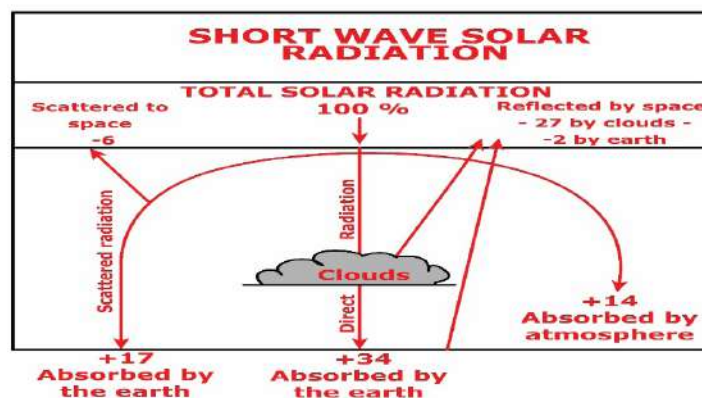
- The **transfer of heat** continues until both the bodies attain the same temperature, or the contact is broken.
- It is important in **heating the lower layers** of the atmosphere.
- **Convection:**
 - It is the process of **vertical heating** of the atmosphere when the air in contact with the earth rises vertically on heating in the form of currents and further transmits the heat of the atmosphere.
 - The **convective transfer of energy is confined only to the troposphere.**
- **Advection:**
 - It is the **transfer of heat** through **horizontal** movement of air.
 - **Horizontal movement** of the air is relatively **more important than the vertical movement.**
 - In **middle latitudes**, most of **diurnal** (day and night) **variation** in daily weather are caused by advection alone.
 - In **tropical regions** particularly in **northern India during summer** season local winds called '**loo**' is the outcome of **advection process.**

Terrestrial Radiation:

- The **insolation** received by the earth is in **short waves forms** and heats up its surface. The **earth** after being heated itself **becomes a radiating body** and it radiates energy to the atmosphere in long wave form. This **energy heats up the atmosphere** from below. This process is known as **terrestrial radiation.**
- **Indirect heating of atmosphere by earth's radiation:** The **long wave radiation** is **absorbed** by the atmospheric gases particularly by carbon dioxide and the other greenhouse gases.
- The atmosphere in turn radiates and transmits heat to the space.
- Finally, the amount of **heat received** from the sun is **returned to space**, thereby maintaining constant temperature at the earth's surface and in the atmosphere.

Heat Budget of the Planet Earth:

- The **earth** as a whole **does not accumulate** or **lose heat** and **maintains its temperature.** This can happen only if the amount of **heat received in the form of insolation equals the amount lost by the earth** through terrestrial radiation.



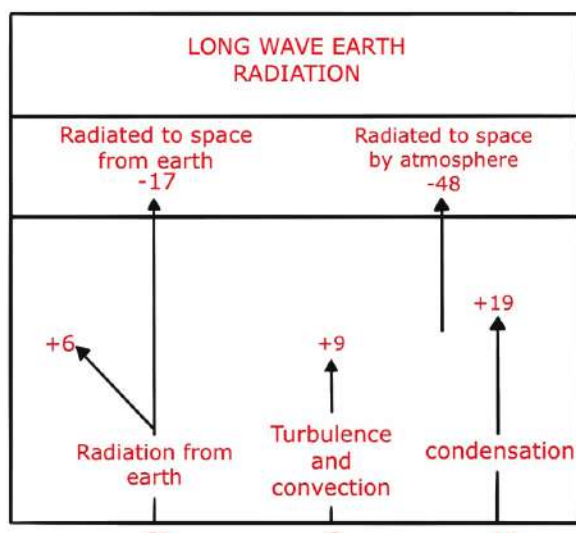


Fig. 9.2: Heat Budget of the Earth

- While passing through the atmosphere some amount of energy is **reflected, scattered and absorbed**. Only the remaining part reaches the earth surface.
- Roughly **35 units are reflected back to space** even before reaching the earth's surface.
 - Of these, **27 units** are reflected back from the top of the clouds and **2 units** from the snow and ice-covered areas of the earth.
 - The reflected amount of radiation is called the **albedo of the earth**.
- The remaining **65 units are absorbed**, **14 units** within the atmosphere and **51 units** by the earth's surface.
- The **earth radiates back 51 units** in the form of terrestrial radiation.
 - Of these, **17 units are radiated** to space directly and the **remaining 34 units are absorbed** by the atmosphere (6 units absorbed directly by the atmosphere, 9 units through convection and turbulence and 19 units through latent heat of condensation).
- **48 units** absorbed by the atmosphere (14 units from insolation +34 units from terrestrial radiation) are also radiated back into space.
 - Thus, the total radiation returning from the earth and the atmosphere respectively is $17+48=65$ units which balance the total of 65 units received from the sun. This is termed the **heat budget or heat balance of the earth**.

Variation in the Net Heat Budget at the Earth's Surface:

- **Some** part of the earth has **surplus radiation** balance while the other part has **deficit**.
- There is a **surplus** of net radiation balance **between 40 degrees north and south** and the regions near the **poles** have a **deficit**.
- The **surplus heat** energy from the tropics is **redistributed pole wards** and as a result the tropics do not get progressively heated up due to the accumulation of excess heat or the high latitudes get permanently frozen due to excess deficit.

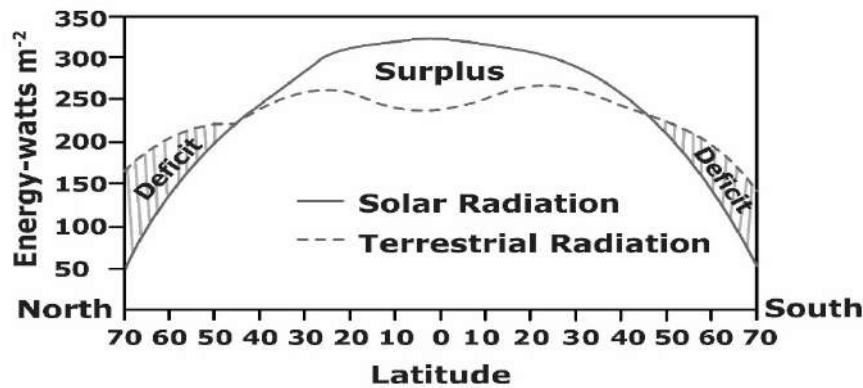


Fig. 9.3: Latitudinal variation in net radiation balance

Temperature:

- The interaction of insolation with the atmosphere and the earth's surface **creates heat** which is measured in terms of temperature.
- The **heat** represents the **molecular movement of particles** comprising a substance and the **temperature** measures in **degrees of hot (or cold)** of a thing (or a place).

Factors Controlling Temperature Distribution: The temperature of air at any place is influenced by:

- **Latitude of the place:**
 - The temperature of a place depends on the **insolation received**.
 - The temperature varies as the **insolation varies according to the latitude**.
- **Altitude of the place:**
 - The atmosphere is **indirectly heated** by terrestrial radiation from below. Therefore, the places near the sea-level record higher temperature than the places situated at higher elevations i.e., the **temperature** generally **decreases** with **increasing height**.
- **Distance from the sea:**
 - **Normal Lapse Rate:** It is the **rate of decrease of temperature with height**.
 - **Variation over sea is less:** The **sea gets heated slowly** as compared to land and loses heat slowly. **Land heats up and cools down quickly**.
 - The places situated **near the sea** come under the **moderating influence** of the sea and land breezes which moderate the temperature.
- **Air-mass and oceanic Currents:**
 - The passage of air masses also affects the temperature like the land and sea breezes.
 - The places, which come under the influence of **warm airmasses** experience **higher temperature** and the places that come under the influence of cold air-masses experience low temperature.
 - The **places** located on the **coast** where the warm ocean currents flow

record **higher temperature** than the places located on the coast where the cold currents flow.

- **Local aspects:**
 - The local aspects also affect the temperature. For example, due to construction of buildings, the area experiences more temperature also called **Heat Island effect**.

Distribution of Temperature:

The January and July months are important to understand global temperature distribution.

- The **Isotherms** are lines joining places having **equal temperature**.
- The effect of the latitude on temperature is well pronounced as the **isotherms are generally parallel to the latitude**.
- The **deviation** from this general trend is **more** pronounced in **January** than in July, especially in the northern hemisphere.
 - **In the northern hemisphere**, the **land surface area is much larger** than in the southern hemisphere. So, the effects of land mass and the ocean currents are well pronounced.
 - In **January**, the **isotherms deviate to the north** over the ocean and to the south over the continent.
 - The **presence of warm ocean currents**, Gulf Stream and North Atlantic drift, make the Northern Atlantic Ocean warmer and the isotherms bend towards the north.
- The **effect of the ocean** is well pronounced in the **southern hemisphere**.
 - The isotherms are more or less

parallel to the latitudes and the variation in temperature is more gradual than in the northern hemisphere.

- **In July**, the **isotherms** generally run **parallel to the latitude**.
- The equatorial oceans record warmer temperature, more than 27°C.
- The **highest range of temperature** is more than 60°C over the **north-eastern part of Eurasian continent** due to **continentality**.
- The **least range of temperature, 3°C**, is found between 20°S and 15°N.

Inversion of Temperature:

- Normally, temperature decreases with increase in elevation and called **normal lapse rate**. At times, the situations are reversed, and the **normal lapse rate is inverted**. It is called **Inversion of temperature**. Inversion is usually of **short duration**.
- **Ideal situation for inversion:** A long winter night with clear skies and still air. The heat of the day is radiated off during the night, and by early morning hours, the earth is cooler than the air above. **Over polar areas, temperature inversion is normal throughout the year**.
- **Effects of the inversion:**
 - Surface inversion promotes **stability** in the **lower layers** of the atmosphere.
 - Smoke and dust particles get collected beneath the inversion layer and spread horizontally to fill the lower strata of the atmosphere.
 - **Dense fogs in mornings** are **common**

occurrences especially during winter season.

- **In Hilly or Mountain areas:**

- The inversion takes place **due to air drainage**.
- Cold air at the hills and mountains, produced during night, flows under the influence of gravity.
- Being heavy and dense, the cold air acts almost like water and moves down the slope to pile up deeply in pockets and valley bottoms with

warm air above. This is called **air drainage**. It **protects plants from frost damages**.

Interesting Points:

- **Plank's Law:** It states that **hotter the body, the more energy it will radiate** and **shorter the wavelength** of that radiation.
- **Specific Heat:** It is the **energy needed** to **raise the temperature** of one gram of substance by one Celsius.





10

Atmospheric Circulation and Weather Systems

Air expands when heated and gets compressed when cooled which results in variations in the atmospheric pressure. It causes the movement of air from high pressure to low pressure, setting the air in motion. It also determines when the air will rise or sink. The vertical rising of moist air cools it down to form the clouds and bring precipitation.

Atmospheric Pressure:

- Human body is subjected to a lot of air pressure and as one moves up the air gets varified and one feels breathless.
- **Atmospheric Pressure:** It is the **weight of a column of air** contained in a unit

area from the mean sea level to the top of the atmosphere. It is expressed in **units of millibar**.

- The average atmospheric pressure is **1,013.2 millibar at the sea level**.
- Due to gravity, the **air at the surface is denser** and hence has higher pressure.
- Air pressure is measured with the help of a **mercury barometer** or the **aneroid barometer**.

Vertical Variation of Pressure:

- In the lower atmosphere, **the pressure decreases rapidly with height**. The decrease amounts to about **1 mb for each 10 m** increase in elevation. It does not always decrease at the same rate.

Table 10.1: Standard Pressure and Temperature at Selected Levels.

Level	Pressure in mb	Temperature °C
Sea level	1,013.25	15.2
1km	898.76	8.7
5km	540.48	-17.3
10km	265.00	-49.7

- The **vertical pressure gradient** force is much **larger** than that of the horizontal pressure gradient. But it is generally balanced by a nearly equal but opposite gravitational force. Hence, there is **no strong upward winds**.

Horizontal Distribution of Pressure:

- Small differences in pressure are significant in terms of wind direction and velocity.
- Horizontal distribution of pressure is studied by drawing **isobars** at constant

levels. **Isobars are lines connecting places having equal pressure**.

- The isobars are measured at any station after being reduced to sea level for purposes of comparison to eliminate the effect of altitude on pressure,
- **Low-pressure system** is enclosed by one or more **isobars** with the **lowest pressure in the centre**.
- **High-pressure system** is also enclosed by one or more **isobars** with the **highest pressure in the centre**.

World Distribution of Sea Level Pressure:

- Near the **equator** the **sea level pressure is low**, and the area is known as **equatorial low**.
- Along 30° N and 30° S are found the **high-pressure areas** known as the **subtropical highs**.
- Further pole wards along 60° N and 60° S, the **low-pressure belts** are termed as the **sub polar lows**.
- Near the poles the **pressure is high**, and it is known as the **polar high**.
- These **pressure belts** are not permanent in nature and they **oscillate with apparent movement of the sun**.
- In the **northern hemisphere**, in winter they move southwards and in the summer northwards.

Forces affecting the Velocity and Direction of Wind:

- **Wind is the air in motion** and blows from high pressure to low pressure.
- The wind at the surface **experiences friction**.
- The rotation of the earth also affects the wind movement. The **force exerted by the rotation of the earth** is known as the **Coriolis force**.
- The horizontal winds near the earth surface respond to the combined effect of **three forces**: the **pressure gradient force**, the **frictional force** and the **Coriolis force**.
- In addition, **the gravitational force** acts downward.

Pressure Gradient Force:

- The **differences in atmospheric pressure produces a force**.

- The **rate of change of pressure** with respect to distance is the **pressure gradient**.
- The **pressure gradient** is strong where the **isobars are close** to each other and is **weak where the isobars are apart**.

Frictional Force:

- It affects the **speed of the wind**.
- It is **greatest** at the **surface** and its influence generally extends up to an elevation of 1-3 km.
- **Over the sea surface the friction is minimal**.

Coriolis Force:

- The rotation of the earth about its axis affects the direction of the wind. This force is called the **Coriolis force** after the French physicist who described it in 1844.
- It **deflects the wind** to the **right direction** in the **northern hemisphere** and to the left in the southern hemisphere. The deflection is more when the wind velocity is high.
- The **Coriolis force is directly proportional to the angle of latitude**. It is **maximum at the poles** and is **absent at the equator**.
- The Coriolis force acts **perpendicular** to the pressure gradient force. The pressure gradient force is **perpendicular to an isobar**.
- The higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind.
- As a result of these two forces operating perpendicular to each other, in the low-pressure areas the wind blows around it.

- It is **zero at the equator** and the **wind blows perpendicular** to the isobars. The low pressure gets filled instead of getting intensified. This is the reason **tropical cyclones** are not formed near the equator.

Pressure and Wind:

- The **velocity** and **direction** of the wind are the **net result** of the **wind generating forces**.

- The winds in upper atmosphere (2-3 km above) are **free from frictional forces** and are mainly controlled by pressure gradient force and Coriolis force.
- When **isobars are straight** and when there is **no friction**, the pressure gradient force is balanced by the Coriolis force and the resultant wind blows parallel to the isobar. This wind is known as the **geostrophic wind**.

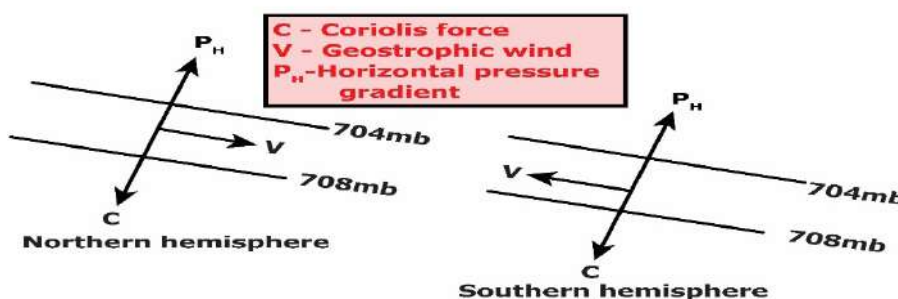


Fig. 10.1: Geostrophic Wind

- The wind circulation around a low pressure is called **cyclonic circulation**. Around a high pressure it is called **anti cyclonic circulation**. The direction is not same.

Table 10.2: Pattern of Wind Direction in Cyclones and Anticyclones

Pressure System	Pressure Condition at the Centre	Pattern of Wind Direction	
		Northern Hemisphere	Southern Hemisphere
Cyclone	Low	Anticlockwise	Clockwise
Anticyclone	High	Clockwise	Anticlockwise

- The wind circulation at the earth's surface around low and high on many occasions is closely related to the wind circulation at higher level.
- Generally, **over low-pressure area** the **air will converge** and rise.
- Over **high-pressure area** the **air will**

subside from above and diverge at the surface.

- Apart from convergence, some eddies, convection currents, orographic uplift and uplift along fronts cause the rising of air, which is essential for the formation of clouds and precipitation.

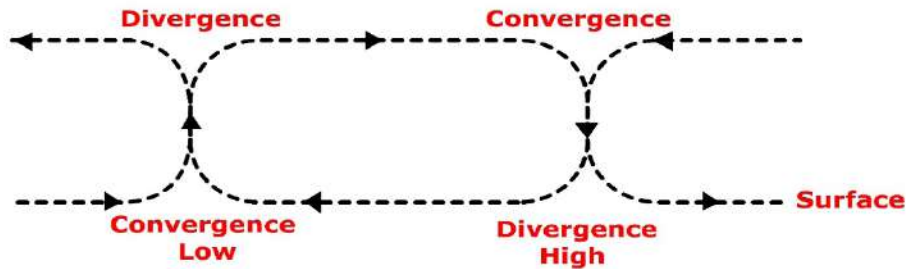


Fig. 10.2: Convergence and divergence of winds

General circulation of atmosphere:

The pattern of the movement of the planetary winds is called the **general circulation of the atmosphere**. The pattern of planetary winds largely depends on:

- Latitudinal variation of atmospheric heating.
- Emergence of pressure belts.

- The migration of belts following apparent path of the sun.
- The distribution of continents and oceans.
- The rotation of earth.

The general circulation of the atmosphere **also sets in motion the ocean water circulation** which influences the earth's climate.

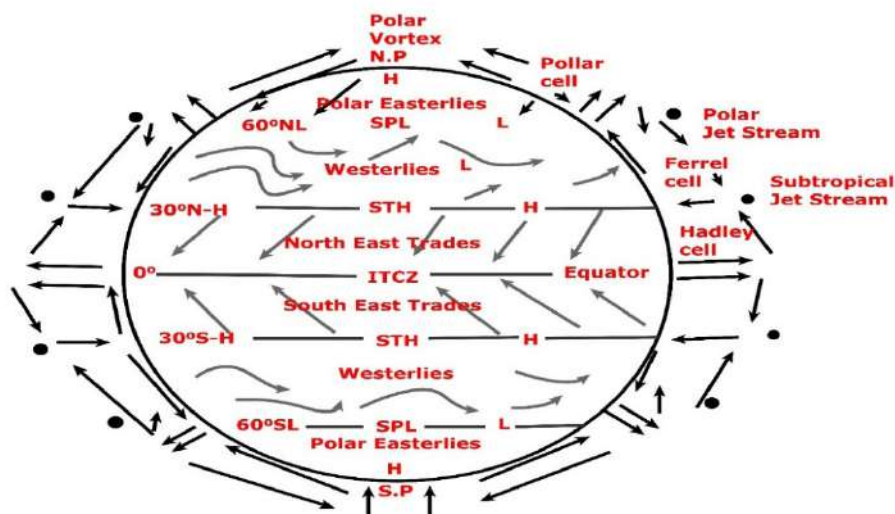


Fig. 10.3: Simplified general circulation of the atmosphere.

- The air at the **Inter Tropical Convergence Zone (ITCZ)** rises because of **convection** caused by high insolation and a low

pressure is created. The winds from the tropics converge at this low-pressure zone.

- The **converged air rises** along with the **convective cell**. It reaches the top of the troposphere up to an altitude of 14 km. and moves towards the poles.
- This causes accumulation of air at about 30° N and S.
- Part of the **accumulated air sinks** to the ground and forms a subtropical high.
- Another reason for sinking is the **cooling of air** when it reaches 30° N and S latitudes.
- Down below near the land surface the **air flows towards the equator** as the **easterlies**.
- The **easterlies** from either side of the equator **converge in the ITCZ**. Such **circulations** from the **surface upwards** and vice-versa are called **cells**. Such a cell in the tropics is called **Hadley cell**.
- In the **middle latitudes**, the circulation is that of sinking cold air that comes from the poles and the rising warm air that blows from the subtropical high.
- At the surface, these winds are called **westerlies** and the cell is known as the **Ferrell cell**.
- At **polar latitudes**, the cold dense air subsides near the poles and blows towards middle latitudes as the **polar easterlies**. This cell is called the **Polar cell**.
- These **three cells** set the **pattern** for the general circulation of the atmosphere.
- The **transfer of heat energy** from lower latitudes to higher latitudes maintains the **general circulation**.
- The general circulation of the atmosphere also affects the oceans.
 - Large-scale winds of the atmosphere initiate large and slow-moving currents of the ocean.
 - Oceans in turn provide input of energy and water vapour into the air.

Seasonal Winds:

- The pattern of wind circulation is **modified in different seasons** due to the shifting of regions of maximum heating, pressure and wind belts.
- The most pronounced effect of such a shift is noticed in the monsoons, especially over southeast Asia.

Local Winds:

- Differences in the heating and cooling of earth surfaces and the cycles those develop daily or annually can create several common, local or regional winds.

Land and Sea Breezes:

- During the **day**, the **land heats up faster** and becomes warmer than the sea. Therefore, **over the land** the **air rises** giving rise to a **low-pressure area**, whereas the **sea** is relatively cool and the pressure over sea is relatively high thus **wind blows from sea to land**.
- In the **night**, the **reversal of condition** takes place. The land loses heat faster and is cooler than the sea. The pressure gradient is from the land to the sea and hence **land breeze results**.

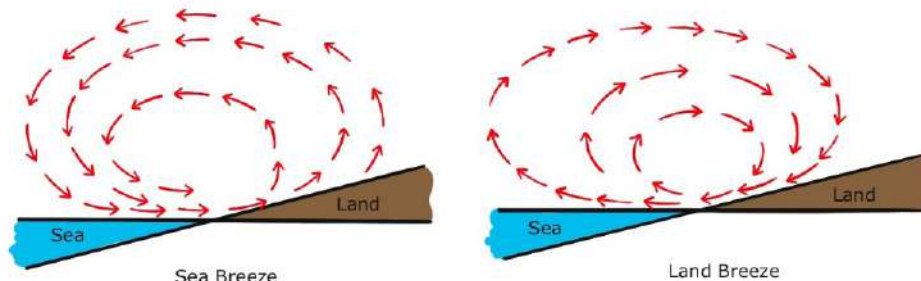


Fig. 10.4: Sea and Land Breeze

Mountain and valley Winds:

- In **mountainous regions**, during the **day** the slopes get heated up and **air moves upslope** and to fill the resulting gap the air from the valley blows up the valley. This wind is known as the **valley breeze**.
- During the **night**, the **slopes get cooled** and the dense air descends into the valley as the **mountain wind**.
- The **cool air**, of the high **plateaus** and ice fields draining into the valley is called **katabatic wind**.
- Another type of warm wind occurs on the leeward side of the mountain ranges.
 - The moisture in these winds, while crossing the mountain ranges **condense and precipitate**.
 - When it descends down the leeward side of the slope the dry air gets warmed up by **adiabatic process**. This dry air may melt the snow in a short time.

Air Masses:

- When the air remains over a **homogenous area** for a sufficiently longer time, it acquires the **characteristics of the area**. The homogenous regions can be the

vast ocean surface or vast plains.

- The air with **distinctive characteristics** in terms of temperature and humidity is called an **airmass**. It is defined as a **large body of air having little horizontal variation in temperature and moisture**.
- The **homogenous surfaces**, over which air masses form, are called the **source regions**.
- The air masses are classified according to the source regions. Following are five major source regions:
 - Warm tropical and subtropical oceans.
 - The subtropical hot deserts.
 - The relatively cold high latitude oceans.
 - The very cold snow-covered continents in high latitudes.
 - Permanently ice-covered continents in the Arctic and Antarctica.
- Accordingly, following **types of airmasses are recognised**: (i) Maritime tropical (mT); (ii) Continental tropical (cT); (iii) Maritime polar (mP); (iv) Continental polar (cP); (v) Continental arctic (cA).
- **Tropical air masses are warm and polar air masses are cold.**

Fronts:

- When **two different air masses meet**, the **boundary zone** between them is called a **front**.
- The process of **formation of the fronts** is known as **frontogenesis**.
- There are **four types of fronts**:
 - **Cold:** When the **cold air** moves **towards the warm** air mass, its contact zone is called the cold front.
 - **Warm:** If the **warm air** mass **moves towards the cold** air mass, the contact zone is a warm front hence it is called warm front.
 - **Stationary Front:** When the front remains **stationary**.
 - **Occluded:** If an air mass is **fully lifted** above the land surface, it is called the occluded front.

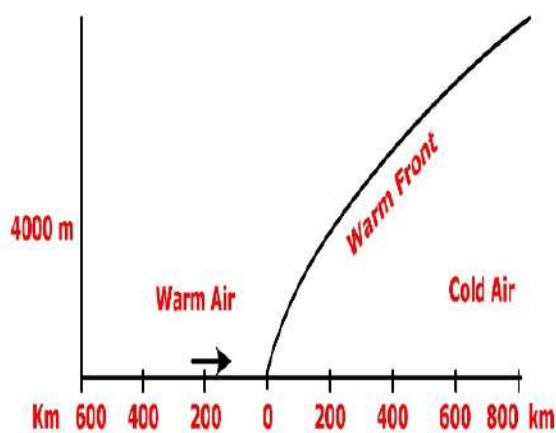


Fig. 10.5: Warm front

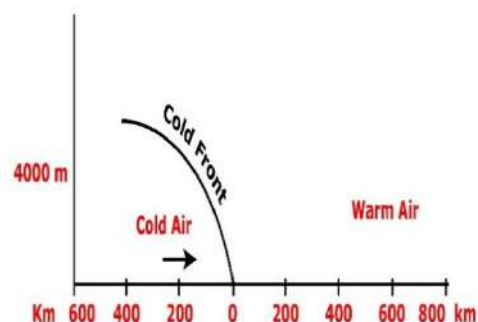


Fig. 10.6: Cold front

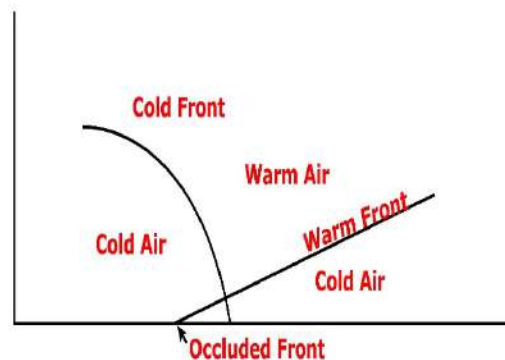


Fig. 10.7: Occluded front

- The **fronts** occur in **middle latitudes** and are characterised by **steep gradient in temperature and pressure**.
- They bring abrupt changes in temperature and cause the air to rise to **form clouds and cause precipitation**.

Extra Tropical Cyclones:

The **systems** developing in the **mid and high latitude**, beyond the tropics are called the **middle latitude** or **extra tropical cyclones**. They form **along the polar front**.

- **Formation of Extra Tropical Cyclone:**

- Initially, the front is stationary.
- In the northern hemisphere, warm air blows from the south and cold air from the north of the front.
- When the **pressure drops** along the **front**, the **warm air moves**

northwards and the cold air moves towards, south setting in motion an **anticlockwise cyclonic circulation**.

- The cyclonic circulation leads to a **well-developed extra tropical cyclone**, with a warm front and a cold front.

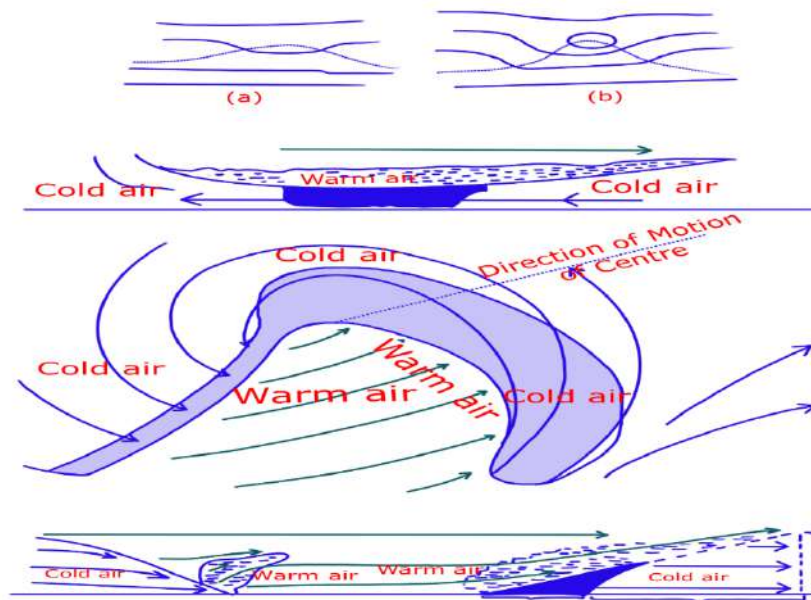


Fig. 10.8: Extra tropical cyclones

- The **warm air glides over the cold air** and a sequence of clouds appear over the sky ahead of the warm front and cause **precipitation**.
- The cold front approaches the warm air from behind and pushes the warm air up. As a result, **cumulus clouds** develop along the cold front.
- The **cold front** moves **faster** than the warm front ultimately overtaking the warm front.
- The warm air is completely lifted up and the front is occluded, and the **cyclone dissipates**.
- The processes of wind circulation both at the surface and aloft are closely interlinked.

Tropical Cyclones:

Tropical cyclones originate and intensify over **warm tropical oceans**.

- Tropical cyclones are **violent storms** that originate over oceans in **tropical areas** and move over to the **coastal areas** bringing about **large-scale destruction** caused by violent winds, very heavy rainfall, and storm surges. This is one of the most **devastating natural calamities**.
- They are known as:
 - **Cyclones** in the Indian Ocean.
 - **Hurricanes** in the Atlantic.
 - **Typhoons** in the Western Pacific and South China Sea.
 - **Willy-willies** in the Western Australia.
- **Favourable conditions for Tropical Cyclones:**
 - Large sea surface with **temperature higher than 27° C**.
 - Presence of the **Coriolis force**.
 - **Small variations** in the **vertical wind speed**.
 - A pre-existing **weak low-pressure area** or **low-level-cyclonic circulation**.
 - **Upper divergence** above the sea level system.

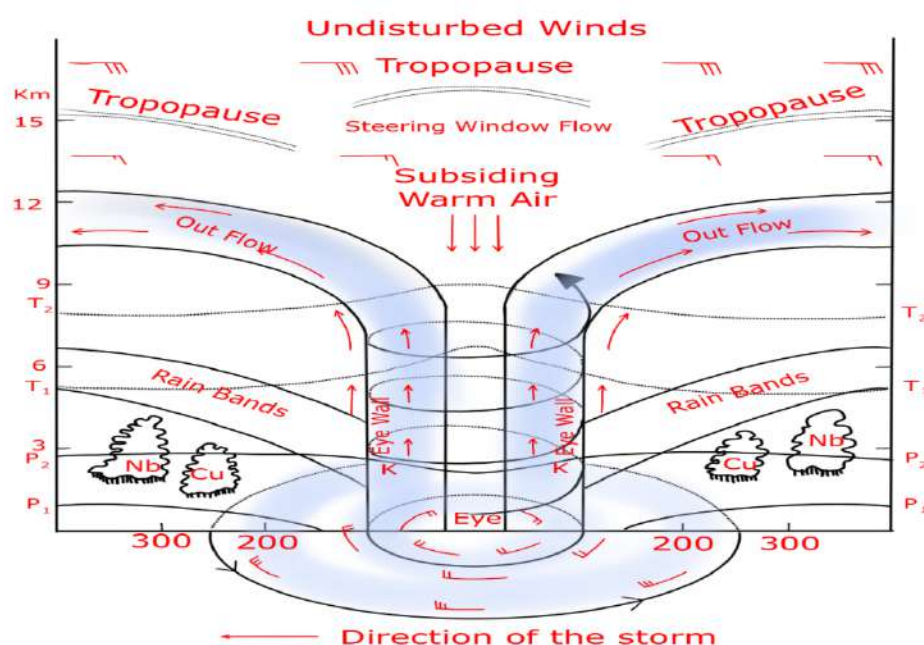


Fig. 10.9: Vertical section of the tropical cyclone

- The **energy** that intensifies the storm, comes from the **condensation process** in the towering **cumulonimbus clouds**, surrounding the centre of the storm.
- On reaching the land, the moisture supply is cut off and the **storm dissipates**.



- The **place** where a **tropical cyclone crosses the coast** is called the **landfall of the cyclone**.
- The cyclones, which cross 20° N latitude generally, **recurve** and they are **more destructive**.
- A **mature tropical cyclone** is characterised by the **strong spirally circulating wind** around the **centre**, called the **eye**. The diameter of the circulating system can vary between 150 and 250 km. The **eye** is a **region of calm** with subsiding air.
- Around the eye is the **eye wall**, where there is a **strong spiralling ascent of air** to greater height reaching the tropopause. The wind reaches maximum velocity in this region and reach as high as 250 km per hour. **Torrential rain occurs here**.
- From the eye wall, **rain bands may radiate**, and **trains of cumulus and cumulonimbus clouds** may drift into the outer region.
- The diameter of the storm over the Bay of Bengal, Arabian sea and the Indian ocean is between 600 - 1200 km.

Table 10.3: Difference between tropical and extra tropical cyclone:

Extra tropical cyclones	Tropical cyclones
They have a clear frontal system .	It doesn't have clear frontal system.
They can originate over the land and sea .	They originate over only on sea and reaching on land they dissipate .
They affect a much larger area as compared to the tropical cyclone.	They affect smaller as compared to extra tropical cyclone.
Wind velocity is static but not violent .	The wind velocity in a tropical cyclone is much higher and it is more destructive .
It moves from west to east .	It moves from east to west .

Thunderstorms:

They are of **short duration**, occurring over a **small area** but are **violent**.

- A thunderstorm is a **well-grown cumulonimbus cloud** producing thunder and lightning.

- **Thunderstorms** are caused by **intense convection** on moist hot days.
- A thunderstorm is characterised by **intense updraft of rising warm air**, which causes the clouds to grow bigger and rise to greater height which causes precipitation. Later, downdraft brings down to earth the cool air and the rain.
- When the clouds extend to heights where sub-zero temperature prevails, **hails are formed**, and they come down as **hailstorm**.
- If there is **insufficient moisture**, a thunderstorm can generate **dust storms**.

Tornadoes:

- From severe thunderstorms sometimes **spiralling wind** descends like a **trunk of an elephant** with great force, with very low pressure at the centre, causing massive destruction on its way. Such a phenomenon is called a **tornado**.
- Tornadoes generally occur in **middle latitudes**.
- The tornado **over the sea** is called **waterspouts**.
- These violent storms are the manifestation of the atmosphere's adjustments to varying energy distribution.
- The potential and heat energies are converted into kinetic energy in these

storms and the restless atmosphere again returns to its stable state.

Interesting Points:

- **EL-Nino:** Warming and cooling of the Pacific Ocean is most important in terms of general atmospheric circulation. The **warm water** of the **central Pacific Ocean** slowly drifts towards South American coast and **replaces** the **cool Peruvian current**. Such appearance of warm water off the coast of Peru is known as the **El Nino**.
- **Southern Oscillation:** The El Nino event is closely associated with the pressure changes in the Central Pacific and Australia. This change in **pressure condition** over Pacific is known as the **southern oscillation**.
- **EL Nino- Southern Oscillation (ENSO):** The **combined phenomenon** of southern oscillation and El Nino is known as **ENSO**. In the years when the ENSO is strong, it affects weather conditions over various regions of the world like the arid west coast of South America receives heavy rainfall, drought occurs in Australia and sometimes in India and floods in China.



Water is present in the atmosphere in **three forms namely gaseous, liquid, and solid**. The moisture in the atmosphere is derived from water bodies through evaporation and from plants through transpiration. There is a **continuous exchange of water** between the atmosphere, the oceans and the continents through the processes of evaporation, transpiration, condensation and precipitation.

Humidity:

Water vapour present in the air is known as humidity. It is expressed quantitatively in different ways.

- **Absolute Humidity:**
 - The **actual amount** of the **water vapour** present in the atmosphere is known as the **absolute humidity**.
 - It is the weight of water vapour per unit volume of air and is expressed in terms of grams per cubic metre.
 - The **ability of the air to hold water vapour depends entirely on its temperature**.
 - It differs from place to place on the surface of the earth.
- **Relative Humidity:**
 - The **percentage of moisture** present in the atmosphere as compared to its full capacity at a given temperature is known as the **relative humidity**.
 - With the change of air temperature, the capacity to retain moisture increases or decreases and the relative humidity is also affected.
 - It is **greater over the oceans** and least over the continents.

Evaporation and Condensation:

The amount of water vapour in the atmosphere is added or withdrawn due to evaporation and condensation, respectively.

Evaporation:

- It is a process by which water is transformed from **liquid to gaseous** state.
- **Heat** is the main cause for evaporation.
- The **temperature** at which the water starts **evaporating** is referred to as the **latent heat of vaporisation**.
- Movement of air replaces the saturated layer with the unsaturated layer. Hence, the greater the movement of air, the greater is the evaporation.

Condensation:

- The transformation of **water vapour into water** is called **condensation**.
- It is caused by the **loss of heat** and **air becomes cool**.
- When water vapour **directly** condenses into **solid** form it is known as **sublimation**.
- In free air, condensation results from cooling around very small particles termed as **hygroscopic condensation nuclei**. Particles of **dust, smoke and salt** from the ocean are particularly good nuclei because they absorb water.
- Condensation also takes place when the moist air comes in contact with some colder object, and it may also take place when the temperature is close to the dew point.
- It **depends** upon the **amount of cooling** and the **relative humidity** of the air.

- It is **influenced** by the volume of air, temperature, pressure and humidity.
 - **Condensation takes place:**
 - When the **temperature of the air is reduced to dew point** with its volume remaining constant.
 - When both the **volume and the temperature are reduced**.
 - When **moisture is added** to the air through evaporation.
 - The most favourable condition for condensation is the **decrease in air temperature**.
 - After condensation, the water vapour or the moisture in the atmosphere takes one of the following forms - **dew, frost, fog and clouds**.
 - **Condensation** takes place when the **dew point is lower** than the **freezing point** as well as **higher** than the **freezing point**.
 - Forms of condensation can be classified on the basis of temperature and location.

Dew: When the **moisture** is **deposited** in the form of **water droplets on cooler surfaces** of solid objects (rather than nuclei in air above the surface) such as stones, grass blades and plant leaves, it is known as **dew**.
 - **Ideal conditions for its formation:** Clear sky, calm air, high relative humidity, and cold and long nights.
 - For the formation of dew, it is necessary that the **dew point** is **above** the **freezing point**.

Frost: Frost forms on cold surfaces when **condensation** takes place **below freezing point** (0°C), i.e., the **dew point is at or below the freezing point**.
 - The excess moisture is deposited in the form of minute ice crystals instead of water droplets.
 - **Ideal conditions for its formation:** They are same as those for the formation of dew, except that the air temperature must be at or below the freezing point.

Fog and mist: When the **temperature** of an air mass containing a large quantity of water vapour **falls suddenly**, condensation takes place within itself on fine dust particles.
 - The **fog** is a **cloud** with its base at or very near to the ground.
 - **Fogs are mini clouds** in which condensation takes place around nuclei provided by the dust, smoke, and the salt particles.
 - The **visibility** becomes **poor to zero** because of the **fog and mist**.
 - In urban and industrial centres, **smoke provides plenty of nuclei** which help the formation of fog and mist. Such a condition when **fog is mixed with smoke**, is described as **smog**.
 - **Difference between Fog and Mist:**
 - **Mist** contains **more moisture** than the fog.
 - In mist, each nuclei contains a thicker layer of moisture. **Mists are frequent over mountains** as the rising warm air up the slopes meets a cold surface.
 - **Fogs** are **drier** than **mist** and they are prevalent where warm currents of air come in contact with cold currents.
- Clouds:**
Cloud is a **mass** of **minute water droplets** or tiny crystals of ice formed by the **condensation of the water vapour** in free air at considerable height. They

take various shapes as the clouds are formed at some height over the surface of the earth.

Clouds are grouped under **four types** according to their height, expanse, density and transparency or opaqueness:

- **Cirrus:**
 - They are formed at **high altitudes** (8,000 - 12,000m).
 - They are **thin and detached clouds** having a feathery appearance.
 - They are **always white** in colour.
- **Cumulus:**
 - They look like **cotton wool**.
 - They are generally formed at a height of 4,000 - 7,000 m.
 - They exist in **patches** and can be seen scattered here and there.
 - They have a **flat base**.
- **Stratus:**
 - As their name implies, these are **layered clouds** covering large portions of the sky.
 - These clouds are generally formed either due to loss of heat or the mixing of air masses with different temperatures.
- **Nimbus:**
 - They are **black or dark grey**.
 - They form at **middle levels** or very near to the surface of the earth.
 - These are **extremely dense** and **opaque** to the rays of the sun.
 - Sometimes, the clouds are so **low** that they seem to touch the ground.
 - These are **shapeless** masses of thick vapour.

A combination of these four basic types can give rise to the following types of clouds:

- **High clouds:** Cirrus, cirrostratus, cirrocumulus.
- **Middle clouds:** Altostratus and altocumulus.
- **Low clouds:** Stratocumulus and nimbostratus and clouds with extensive vertical development are cumulus and cumulonimbus.

Precipitation:

The process of continuous condensation in free air helps the condensed particles to grow in size. When the resistance of the air fails to hold them against the force of gravity, they **fall on to the earth's surface**. So, after the condensation of water vapour, the **release of moisture** is known as **precipitation**. This may take place in **liquid or solid form**.

- The precipitation in the form of **water** is called **rainfall**.
- When the **temperature is lower** than the **0°C**, precipitation takes place in the form of fine flakes of **snow** and is called **snowfall**.
- Moisture is released in the form of **hexagonal crystals**. These crystals form **flakes of snow**.
- **Sleet:**
 - It is **frozen raindrops** and **refrozen melted snow-water**.
 - When a layer of air with the temperature above freezing point overlies a subfreezing layer near the ground, precipitation takes place in the form of sleet.
 - Raindrops, which leave the warmer air, encounter the colder air below. As a result, they **solidify and reach the ground as small pellets**.

- **Hailstones:**

- Sometimes, drops of rain after being released by the clouds become solidified into small rounded solid pieces of ice and which reach the surface of the earth are called **hailstones**.
- These are formed by the **rainwater** passing through the **colder layers**.
- Hailstones have several **concentric layers of ice** one over the other.

Types of Rainfall:

On the basis of origin, rainfall may be classified into **three main types: the convectional, orographic and the cyclonic or frontal**.

Convectional Rainfall:

- The **air** on being heated, **becomes light** and rises up in convection currents. As it rises, **it expands** and loses heat and consequently, condensation takes place and cumulous clouds are formed.
- Heavy rainfall takes place **with thunder and lightning**, but this **does not last long**.
- Such rain is common in the **summer** or in the **hotter part** of the day.
- It is very common in the **equatorial regions** and interior parts of the continents, particularly in the northern hemisphere.

Orographic rain:

- When the **saturated air mass** comes **across a mountain**, it is forced to ascend and as it rises, it expands; the temperature falls, and the moisture is condensed. It is also known as the **relief rain**.

- The **windward slopes** receive **greater rainfall**.

- When these winds reach the other slope, they descend, and their temperature rises. Then their capacity to take in moisture increases and hence, these **leeward** slopes remain **rainless and dry**. The area situated on the leeward side, which gets less rainfall is known as the **rain-shadow area**.

Cyclonic rainfall: It is the rainfall caused by the occurrence of tropical and extra-tropical cyclones.

World Distribution of Rainfall:

Different places on the earth's surface receive different amounts of rainfall in a year and that too in different seasons.

- The rainfall **decreases** from **equator towards the poles**.
- The **coastal areas** of the world **receive greater amounts of rainfall** than the interior of the continents.
- The **rainfall is more over the oceans** than on the landmasses of the world because of being great sources of water.
- The **rain** is **heavier** on the **eastern coasts** and goes on decreasing towards the west **between the latitudes 35 degree and 40-degree N and S** of the equator.
- **Between 45 degree and 65-degree N and S** of equator, due to the **westerlies**, the rainfall is first received on the **western margins of the continents** and it goes on decreasing towards the east.
- Wherever **mountains** run **parallel** to the coast, **the rain is greater on the coastal plain, on the windward side** and it **decreases towards the leeward side**. On the basis of the total amount of annual precipitation, **major precipitation**

regimes of the world are identified as follows:

- **Heavy rainfall (over 200 cm per annum):** The equatorial belt, the windward slopes of the mountains along the western coasts in the cool temperate zone.
- **Moderate rainfall (200 cm per annum):** Interior continental areas, coastal areas of the continents receive moderate amount of rainfall.
- **Low rainfall (50 - 100 cm per annum):** Central parts of the tropical land and the eastern and interior parts of the temperate lands.
- **Very low rainfall (less than 50 cm per annum):** Areas lying in the rain shadow

zone of the interior of the continents and high latitudes.

In some region's rainfall is distributed evenly throughout the year such as in the equatorial belt and in the western parts of cool temperate regions.

Interesting Points:

- **Dew Point:**
 - The air containing moisture to its full capacity at a given temperature is said to be **saturated**.
 - The **temperature** at which **saturation occurs** in a given sample of air is known as **dew point**.



12

World Climate and Climate Change

The world climate can be studied by organising information and data on climate and synthesising them in smaller units for easy understanding, description, and analysis.

Three broad approaches for classifying Climate:

- **Empirical classification:** It is based on observed data, particularly on temperature and precipitation.
- **Genetic classification:** It attempts to organise climates according to their causes.
- **Applied classification:** It is for specific purposes.

Koeppen's Scheme of Classification of Climate:

The most widely used classification of climate is the **empirical climate**

classification scheme developed by **V. Koeppen**.

- He identified a close **relationship** between the **distribution of vegetation and climate**.
- He selected certain values of **temperature and precipitation** and related them to the **distribution of vegetation** and used these values for classifying the climates.
- It is an **empirical classification** based on **mean annual** and **mean monthly temperature** and precipitation data.
- He introduced the use of **capital and small letters** to designate climatic groups and types.
- He recognised **five major climatic groups**, **four** of them are based on **temperature** and **one** on **precipitation**.
- **Capital letters:** A, C, D and E delineate humid climates and B dry climates.

Table 12.1: Climatic Groups According to Koeppen

Group	Characteristics
A - Tropical	Average temperature of the coldest month is 18° C or higher
B - Dry Climates	Potential evaporation exceeds precipitation
C - Warm Temperate	The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3°C but below 18°C
D - Cold Snow Forest Climates	The average temperature of the coldest month is minus 3° C or below
E - Cold Climates	Average temperature for all months is below 10° C
H - High Land	Cold due to elevation

Table 12.2: Climatic Types According to Koeppen

Group	Type	Letter Code	Characteristics
A-Tropical Humid Climate	Tropical wet	Af	No dry season
	Tropical monsoon	Am	Monsoonal, short dry season
	Tropical wet and dry	Aw	Winter dry season
	Subtropical steppe	BSh	Low-latitude semi arid or dry
B-Dry Climate	Subtropical desert	BWh	Low-latitude arid or dry
	Mid-latitude steppe	BSk	Mid-latitude semi arid or dry
	Mid-latitude desert	BWk	Mid-latitude arid or dry
C-Warm temperate (Mid-latitude) Climates	Humid subtropical	Cfa	No dry season, warm summer
	Mediterranean	Cs	Dry hot summer
	Marine west coast	Cfb	No dry season, warm and cool summer
D-Cold Snow-forest Climates	Humid continental	Df	No dry season, severe winter
	Subarctic	Dw	Winter dry and very severe
E-Cold Climates	Tundra	ET	No true summer
	Polar ice cap	EF	Perennial ice
H-Highland	Highland	H	Highland with snow cover

- The climatic groups are **subdivided** into types, designated by **small letters**, based on seasonality of precipitation and temperature characteristics.
 - The **seasons of dryness** are indicated by the small letters: f, m, w and s
 - f**: no dry season.
 - m**: monsoon climate.
 - w**: winter dry season.
 - s**: summer dry season.
 - The **small letters a, b, c and d** refer to the degree of **severity of temperature**.
 - The **B- Dry Climates** are subdivided using the capital **letters S for steppe or semi-arid and W for deserts**.
- Group A: Tropical Humid Climates**
- Tropical humid** climates exist **between Tropic of Cancer and Tropic of Capricorn**.
 - The sun being overhead throughout the year and the presence of Inter Tropical Convergence Zone (ITCZ) make the climate hot and humid.
 - Annual range of temperature is very low and annual rainfall is high.
 - The tropical group is divided into three types, namely **Af- Tropical wet climate, Am - Tropical monsoon climate, Aw- Tropical wet and dry climate**.
- Tropical Wet Climate (Af):**
- Regions:** It is found **near the equator** and the major areas are the Amazon Basin in South America, western equatorial Africa and the islands of East Indies.
 - Rainfall:** **Significant amount** of rainfall occur, every month of the year, as **thunder showers in the afternoon**.

- **Temperature:** The temperature is **uniformly high** and annual range of the temperature is negligible. The maximum temperature on any day is around 30°C while the minimum temperature is around 20°C.
- **Vegetation and Biodiversity:** **Tropical evergreen** forests with dense canopy cover and large biodiversity are found in this climate.

Tropical Monsoon Climate (Am):

- **Regions:** It is found over the **Indian sub-continent**, North Eastern part of South America and Northern Australia.
- **Rainfall:** Heavy **rainfall occurs mostly in summer** and mostly **winter is dry**.
- **Vegetation and Biodiversity:** It has **monsoon forest**. **Tree shed their leaves during dry period**. In this region, biodiversity is abundantly found.

Tropical Wet and Dry Climate (Aw):

- **Regions:**
 - It occurs north and **south of Af type** climate regions.
 - It borders with dry climate on the western part of the continent and Cf or Cw on the eastern part.
 - Extensive Aw climate is found to the north and south of the Amazon forest in Brazil and adjoining parts of Bolivia and Paraguay in South America, Sudan and south of Central Africa.

- **Rainfall:**

- The annual rainfall in this climate is considerably less than that in Af and Am climate types and is variable also.
- The wet season is shorter, and the dry season is longer with the **drought being more severe**.

- **Temperature:** Temperature is **high** throughout the year and **diurnal ranges of temperature are the greatest** in the dry season.
- **Vegetation and Biodiversity:** **Deciduous forest** and tree-shredded grasslands occur in this climate.

Dry climate (B)

Dry climates are characterised by very low rainfall that is not adequate for the growth of plants.

- **Regions:** These climates cover a very large area of the planet extending over large latitudes from **15°-60° north and south of the equator**.
 - **At low latitudes**, from 15° - 30°, they occur in the area of subtropical high where subsidence and inversion of temperature do not produce rainfall.
 - **In middle latitudes**, from 35° - 60° north and south of equator, they are confined to the interior of continents where maritime-humid winds do not reach and to areas often surrounded by mountains.

On the western margin of the continents, adjoining the cold current, particularly over the west coast of South America, they extend more equator wards and occur on the coast land.

- Dry climates are divided into **steppe** or **semi-arid climate (BS)** and **desert climate (BW)**.
- They are further subdivided as subtropical steppe (BSh) and subtropical desert (BWh) at latitudes from 15° - 35° and mid-latitude steppe (BSk) and mid-latitude desert (BWk) at latitudes between 35° - 60°.

Subtropical Steppe (BSh) and Subtropical Desert (BWh) Climates:

- Subtropical steppe (BSh) and subtropical desert (BWh) have common precipitation and temperature characteristics.
- Located in the **transition zone** between humid and dry climates, **subtropical steppe** receives slightly **more rainfall** than the desert, adequate enough for the growth of sparse grasslands.
- The **rainfall** in both the climates is **highly variable**.
 - The variability in the rainfall affects the life in the steppe much more than in the desert, more often causing famine.
 - Rain occurs in short intense thundershowers in deserts and is ineffective in building soil moisture.
- **Fog is common in coastal deserts bordering cold currents.**
- Maximum temperature in the summer is **very high**. The highest shade temperature of 58° C was recorded at Al Aziziyah, Libya on 13 September 1922. **The annual and diurnal ranges of temperature are also high.**

Warm Temperate (Mid-Latitude) Climates-C:

- **Regions:** They extend from **30° - 50°** of **latitude** mainly on the eastern and western margins of continents.
- These climates generally have warm summers with mild winters.

Types of Wet Temperate (Mid-Latitude)

Humid subtropical climate (Cwa):

- It occurs **poleward** of **Tropic of Cancer and Capricorn**, mainly in North Indian plains and South China interior plains.
- The climate is similar to Aw climate except that the temperature in winter is warm.

Mediterranean Climate (Cs):

- It occurs around **Mediterranean Sea**, along the **west coast of continents** in **subtropical latitudes** between 30° - 40° latitudes. For example - Central California, Central Chile, along the coast in south eastern and south western Australia.
- These areas come under the **influence** of **sub-tropical high** in **summer** and **westerly wind** in **winter**.
- The climate is characterised by hot, dry summer and mild, rainy winter.
- Monthly average temperature in summer is around 25°C and in winter below 10°C.
- The **annual precipitation** ranges between **35 - 90 cm**.

Humid Subtropical (Cfa) Climate:

- It lies on the **eastern parts** of the continent in subtropical latitudes.
- In this region the **air masses** are generally **unstable** and cause rainfall throughout the year.
- **Regions:** They occur in eastern USA, southern and eastern China, southern Japan, north-eastern Argentina, coastal south Africa and eastern coast of Australia.
- **Precipitation:** The annual averages of precipitation vary from **75-150 cm**. Thunderstorms in summer and frontal precipitation in winter are common.
- **Temperature:** Mean monthly temperature in summer is around 27°C, and in winter it varies from 5°-12° C. **The daily range of temperature is small.**

Marine West Coast Climate (Cfb):

- It is located **poleward** from the Mediterranean climate on the west coast of the continents.
- **Regions:** North-western Europe, west coast of North America, north of California, southern Chile, south-eastern Australia and New Zealand.
- **Temperature:** The temperature is moderate and in winter, it is warmer for its latitude the mean temperature in summer months ranges from 15°-20°C and in winter 4°-10°C. The annual and daily ranges of temperature are small.
- **Precipitation:** It **occurs throughout the year** and varies greatly from 50-250cm.

Cold Snow Forest Climate:

They occur in the large continental area in the **northern hemisphere** between

40°-70° north latitudes in Europe, Asia and North America. The severity of winter is more pronounced in higher latitudes. They are divided into **two types:**

Cold climate with humid winters (Df):

- They occur poleward of marine west coast climate and mid latitude steppe.
- The winters are cold and snowy.
- The frost-free season is short.
- The annual ranges of temperature are large.
- The weather changes are abrupt and short.
- Poleward, the winters are more severe.

Cold Climate with Dry Winters (Dw):

- **Regions:** It occurs mainly over **North-eastern Asia**.
- The development of pronounced winter anti cyclone and its weakening in summer sets in monsoon like reversal of wind in this region.
- **Temperature:** Poleward summer temperatures are lower and winter temperatures are extremely low with many locations experiencing below freezing point temperatures for up to seven months in a year.
- **Precipitation:** It occurs in summer and the annual precipitation is low from 12-15 cm.

Polar Climates (E):

They exist poleward beyond 70° latitude. Polar climates consist of **two types:**

Tundra Climate (ET):

- The tundra climate (ET) is so called after the types of vegetation, like **low**

growing mosses, lichens and flowering plants.

- This is the region of **permafrost** where the sub soil is permanently frozen.
- The **short growing season** and water logging support only low growing plants.
- During summer, the tundra regions have very long duration of day light.

Ice Cap Climate (EF):

- It occurs over **interior Greenland** and **Antarctica**.
- **Temperature:** Even in summer, the temperature is below freezing point.
- **Precipitation:** This area receives very little precipitation.
- The snow and ice get accumulated and the mounting pressure causes the deformation of the ice sheets and they break.
- They move as icebergs that float in the Arctic and Antarctic waters.
- Plateau Station, Antarctica, 79°S, portray this climate.

Highland Climates (H):

- They are governed by **topography**. In high mountains, large changes in mean temperature occur over short distances.
- Precipitation types and intensity also vary spatially across high lands.
- There is **vertical zonation** of layering of climatic types with elevation in the mountain environment.

Climate Change:

The planet earth has witnessed many variations in climate since beginning. There are various evidence showing that climate change is natural and

continuous process:

- **Geological records** show alteration of glacial and inter-glacial periods.
- The geomorphological features, especially in high altitudes and high latitudes, exhibit traces of advances and retreats of glaciers.
- The **sediment deposits in glacial lakes** also reveal the occurrence of warm and cold periods.
- The **rings in the trees** provide clues about wet and dry periods.
- The Rajasthan desert experienced wet and cool climate around 8,000 B.C.

Stages of Climate Change:

- In the geological past, the earth was warm some 500-300 million years ago, through the Cambrian, Ordovician and Silurian periods.
- During the Pleistocene epoch, glacial and inter-glacial periods occurred, the last major peak glacial period was about 18,000 years ago.
- The **present inter-glacial** period started **10,000 years ago**.

Causes of climate change: They can be grouped into **astronomical** and **terrestrial causes**.

Astronomical causes: They are the **changes in solar output** associated with **sunspot activities**.

- **Sunspot activities:** Sunspots are **dark and cooler patches on the sun** which increase and decrease in a cyclical manner.
 - According to some meteorologists, when the **number of sunspots increase, cooler and wetter weather** and greater storminess **occur**.

- A decrease in sunspot numbers is associated with warm and drier conditions.
- **Milankovitch Oscillations:** It infers cycles in the variations in the **earth's orbital** characteristics around the sun, the wobbling of the earth and the changes in the earth's axial tilt. All these alter the amount of insolation received from the sun, which in turn, might have a bearing on the climate.

Terrestrial Causes:

- **Volcanism:** Volcanic eruption throws up lots of **aerosols** into the atmosphere which remain in the atmosphere for a considerable period of time **reducing the sun's radiation** reaching the Earth's surface. After the recent Pinatoba and El Cion volcanic eruptions, the average temperature of the earth fell to some extent for some years.
- **Anthropogenic Effect:** There is increasing trend in the **concentration of greenhouse gases** in the atmosphere.

Impacts of climate change in 19th century:

- Variability in climate occurs all the time. The nineties decade of the last century witnessed **extreme weather events**. The 1990s recorded the warmest temperature of the century and some of the worst floods around the world.
- The **worst devastating drought in the Sahel region**, south of the Sahara Desert, from 1967-1977 is one such variability.
- Historical records of crop yield or **crop failures**, of floods and migration of people talk about the effects of

changing climate.

- A number of times Europe witnessed warm, wet, cold and dry periods, the significant episodes were the warm and dry conditions in the tenth and eleventh centuries, when the Vikings settled in Greenland.
- Europe witnessed **"Little Ice Age"** from **1550 to about 1850**.
- From about 1885-1940, world temperature showed an upward trend.
- After 1940, the rate of increase in temperature slowed down.

Global Warming:

- Due to the **presence of greenhouse gases**, the atmosphere is behaving like a greenhouse.
- Atmosphere starts **absorbing the vast majority of long wave radiation** emitted upwards by the earth's surface. The gases that **absorb long wave radiation** are called **greenhouse gases**.
- The processes that **warm the atmosphere** are often collectively referred to as the **greenhouse effect**.

Greenhouse Gases (GHGs):

- The **primary GHGs** are Carbon dioxide (CO₂), Chlorofluorocarbons (CFCs), Methane (CH₄), Nitrous oxide (N₂O) and Ozone (O₃).
- Some other gases such as nitric oxide (NO) and carbon monoxide (CO) easily react with GHGs and affect their concentration in the atmosphere.
- **Effectiveness of any GHG molecule depend on:**
 - The magnitude of the increase in its concentration.

- Its lifetime in the atmosphere.
- The wavelength of radiation it absorbs.
- The **largest concentration** of GHGs in the atmosphere is **carbon dioxide**.
- The emission of carbon dioxide comes mainly from fossil fuel combustion (oil, gas and coal).
- Forests use CO_2 in their growth. Due to changes in land use, **Deforestation increases the concentration of CO_2** .
- The more time the GHG molecule remains in the atmosphere, the longer it will take for earth's atmospheric system to recover from any change brought about by the latter.
- The **chlorofluorocarbons (CFCs)** are highly effective and are products of human activity.
- **Ozone** which absorbs ultraviolet radiation in the stratosphere is very effective in absorbing terrestrial radiation when it is present in the lower troposphere.
- Ozone occurs in the stratosphere where ultra-violet rays convert oxygen into ozone.
- The **depletion of ozone** concentration in the **stratosphere** is called the **ozone**

hole. Large depletion of ozone occurs over Antarctica.

International effort to reduce GHGs:

- **Kyoto protocol** proclaimed in **1997** and went into effect in 2005. It bounds the **35 industrialised countries** to **reduce** their emissions by the year 2012 to 5 per cent less than the levels prevalent in the year 1990.

Interesting Points:

- **Greenhouse:** This term is derived from the analogy to a greenhouse used in **cold areas for preserving heat**. A greenhouse is made up of glass.
 - The glass which is transparent to incoming short wave solar radiation is **opaque to outgoing long wave radiation**.
 - The glass, therefore, allows in more radiation and **prevents the long wave radiation going outside the glass house**, causing the temperature inside the glasshouse structure **warmer** than outside.
- The **Great Plains of the United States** is described as the **dust bowl**.



Unit V: Water (Oceans)

Water is an essential component of all life forms that exists over the surface of the earth. Water is a rare commodity in our solar system. There is no water on the sun or anywhere else in the solar system.

Hydrological Cycle:

The hydrological cycle is the **circulation of water** within the **earth's hydrosphere** in different forms i.e., the liquid, solid and the gaseous phases. It also refers to the **continuous exchange of water** between the oceans, atmosphere, land surface and subsurface and the organisms.

- Water is a **cyclic resource** and can be used and re-used.
- Water also undergoes a cycle from the ocean to land and land to ocean.
- The hydrological cycle describes the **movement of water on, in, and above the earth**.
- The distribution of water on earth is quite uneven as many locations have plenty of water while others have very limited quantity.
- About **71 per cent** of the **planetary water** is found in the **oceans** and the remaining is held as freshwater in glaciers and icecaps, groundwater sources, lakes, soil moisture, atmosphere, streams and within life.

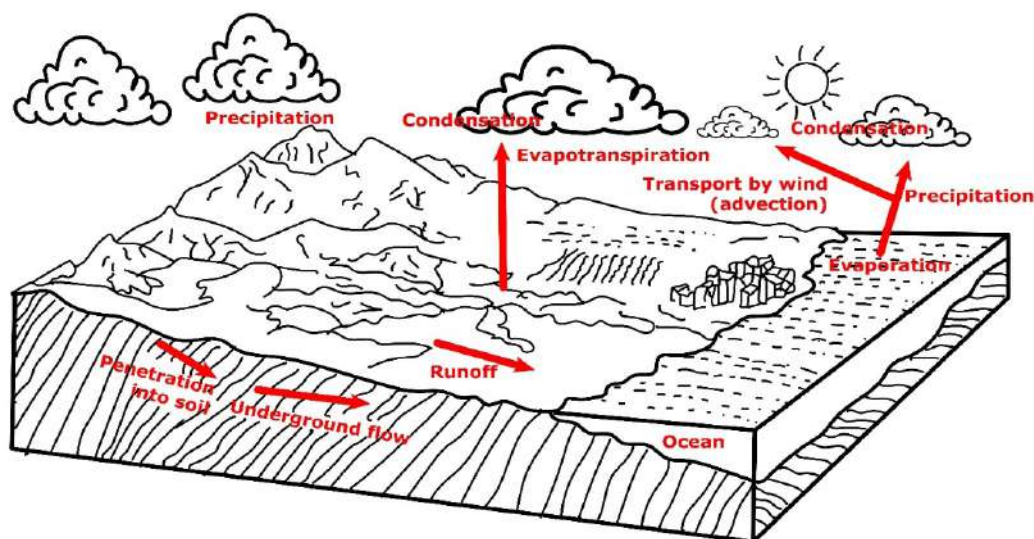


Fig. 13.1: Hydrological Cycle

- Nearly **59 per cent** of the water that falls on land **returns to the atmosphere** through evaporation from over the oceans as well as from other places.
- The remainder runs-off on the surface, infiltrates into the ground or a part of it becomes glacier.
- The renewable water on the earth is constant while the demand is increasing

tremendously which leads to water crisis in different parts of the world both spatially and temporally.

Table 13.1: Components and Processes of the Water Cycle

Components	Processes
Water storage in oceans	Evaporation Evapotranspiration Sublimation
Water to the atmosphere	Condensation Precipitation
Water storage in ice and snow	Snowmelt runoff to streams
Surface runoff	Stream flow freshwater storage infiltration
Groundwater storage	Groundwater discharge springs

Relief of the Ocean Floor:

The oceans are confined to the great depressions of the earth's outer layer.

- The oceans, unlike the continents, merge so naturally into one another that it is hard to demarcate them.
- The geographers have divided the oceanic part of the earth into **five oceans**, namely the Pacific, the Atlantic, the Indian, Southern Ocean and the Arctic.
- The various seas, bays, gulfs and other inlets are parts of these large oceans.
- A **major portion** of the ocean floor is found between **3-6 km** below the sea level.
- The 'land' under the waters of the oceans, that is, the ocean floor exhibits complex and varied features as those observed over the land.
- The floors of the oceans are rugged with the world's largest mountain ranges,

deepest trenches and the largest plains. These features are formed, like those of the continents, by the factors of tectonic, volcanic and depositional processes.

Division of the Ocean Floors:

- The ocean floors can be divided into **four major divisions**: The Continental Shelf, the Continental Slope, the Deep-Sea Plain and the Oceanic Deep.
- Besides, these divisions there are also major and minor relief features in the ocean floors like ridges, hills, sea mounts, guyots, trenches, canyons, etc.

Major Divisions:

Continental shelf: It is the **extended margin** of each continent occupied by relatively **shallow seas** and gulfs.

- It is the **shallowest part of the ocean** showing an average **gradient of 1° or even less**.
- The **shelf** typically **ends** at a very **steep slope**, called the **shelf break**.
- The **width** of the continental shelf is **not uniform** in all the oceans and seas and its average width is about 80 km.
- The shelves are almost absent or very narrow along some of the margins like the coasts of Chile, the west coast of Sumatra, etc. On the contrary, **the Siberian shelf** in the Arctic Ocean, the **largest in the world**, stretches to 1,500 km in width.
- The **depth** of the shelves also **varies**. It may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m.
- The continental shelves are covered with **variable thicknesses of sediments**

brought down by rivers, glaciers, wind, from the land and distributed by waves and currents.

- Massive **sedimentary deposits** received over a long time by the continental shelves, become the **source of fossil fuels**.

Continental Slope: It **connects** the **continental shelf** and the **ocean basins**.

- It **begins** where the **bottom** of the **continental shelf sharply drops off** into a steep slope.
- The gradient of the slope region varies between **2-5°**.

- The depth of the slope region varies between 200 and 3,000 m.
- The **slope boundary indicates the end of the continents**.
- **Canyons** and **trenches** are observed in this region.

Deep Sea Plains: They are **gently sloping areas** of the ocean basins.

- These are the **flattest** and **smoothest** regions of the world.
- The depths vary between 3,000 and 6,000m.
- These plains are covered with **fine-grained sediments** like clay and silt.

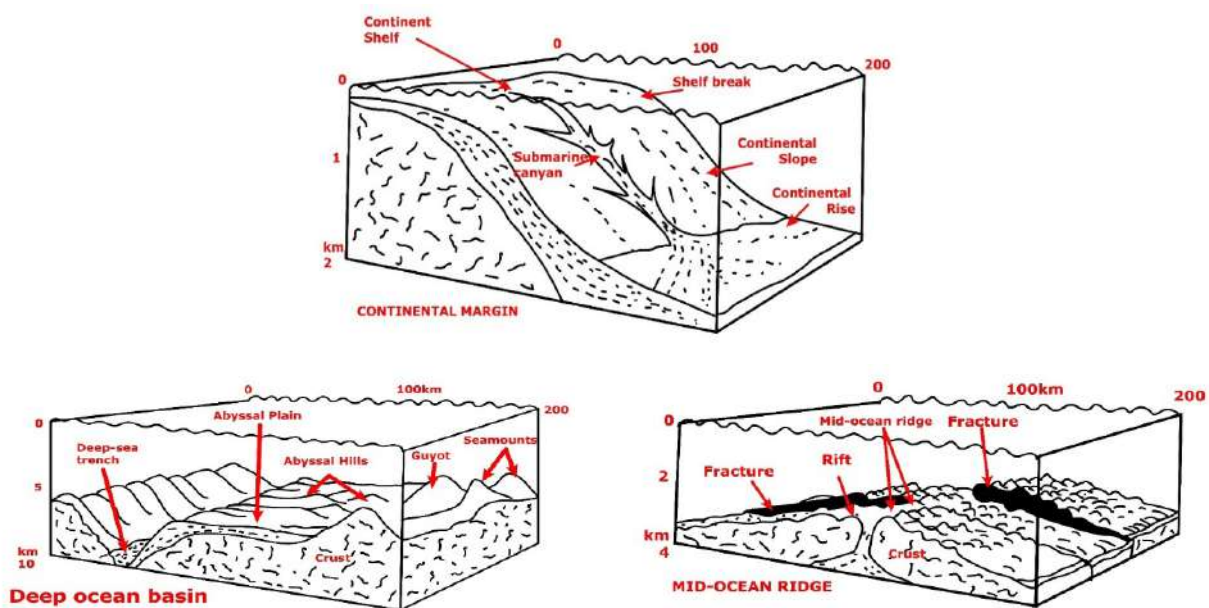


Fig. 13.2: Relief features of ocean floors

Oceanic Deepes and Trenches: These areas are the **deepest parts** of the oceans.

- The **trenches** are relatively **steep sided, narrow basins**.

- They are some **3-5 km deeper** than the surrounding ocean floor.
- They occur at the **bases of continental slopes** and along island arcs and are associated with active volcanoes and

strong earthquakes and are significant in the study of plate movements.

- As many as 57 deeps have been explored so far; of which 32 are in the Pacific Ocean; 19 in the Atlantic Ocean and 6 in the Indian Ocean.

Minor Relief Features:

Some minor but significant features predominate in different parts of the oceans.

Mid-Oceanic Ridges:

- It is **composed** of **two chains of mountains** separated by a large depression.
- The mountain ranges can have peaks as high as 2,500 m and some even reach above the ocean's surface. For example, Iceland is a part of the mid-Atlantic Ridge.

Seamount:

- It is a **mountain** with **pointed summits**, rising from the seafloor that does not reach the surface of the ocean.
- Seamounts are **volcanic** in origin.
- These can be 3,000–4,500 m tall.
- For example, The **Emperor seamount** is an extension of the Hawaiian Islands in the Pacific Ocean.

Submarine Canyons:

- These are **deep valleys**, some of them can be compared with the Grand Canyon of the Colorado river.
- They are sometimes found cutting across the continental shelves and slopes, often extending from the mouths of large rivers.

- The **Hudson Canyon** is the best-known submarine canyon in the world.

Guyots:

- It is a **flat-topped seamount**.
- They show evidence of gradual subsidence through stages to become **flat topped submerged mountains**.
- It is estimated that more than 10,000 seamounts and guyots exist in the Pacific Ocean alone.

Atoll:

- These are **low islands** found in the **tropical oceans** consisting of coral reefs surrounding a central depression.
- It may be a part of the sea (lagoon), or sometimes form enclosing a body of fresh, brackish, or highly saline water.

Temperature of Ocean Waters:

There are spatial and vertical variations of temperature in various oceans of the world. Ocean waters get heated up by the solar energy just as land. **The process of heating and cooling of the oceanic water is slower than land.**

Factors affecting Temperature Distribution:

- **Latitude:** The **temperature** of surface water **decreases** from the **equator towards the poles** because the amount of insolation decreases poleward.
- **Unequal distribution of land and water:** The **oceans** in the **northern hemisphere** receive **more heat** due to their contact with larger extent of land than the oceans in the southern hemisphere.

- **Prevailing wind:** The winds blowing from the land towards the oceans **drive warm surface water** away from the coast resulting in the upwelling of cold water from below.
 - It results into the **longitudinal variation** in the temperature.
 - Contrary to this, the **onshore winds pile up warm water** near the coast and this **raises the temperature**.
- **Ocean currents:** Warm ocean currents **raise the temperature** in **cold areas** while the cold currents decrease the temperature in warm ocean areas. Gulf stream (warm current) raises the temperature near the eastern coast of North America and the West Coast of Europe while the Labrador current (cold current) lowers the temperature near the north-east coast of North America.
- The **enclosed seas** in the low latitudes record relatively higher temperature than the open seas, whereas the enclosed seas in the high latitudes have lower temperature than the open seas.

Horizontal and Vertical Distribution of Temperature:

The temperature-depth profile for the ocean water shows how the temperature decreases with the increasing depth. The profile shows a boundary region between the surface waters of the ocean and the deeper layers.

Vertical Distribution of the temperature:

- The boundary usually begins around 100 - 400 m below the sea surface and extends several hundred of metres downward. This **boundary region**, from

where there is a **rapid decrease of temperature**, is called the **thermocline**.

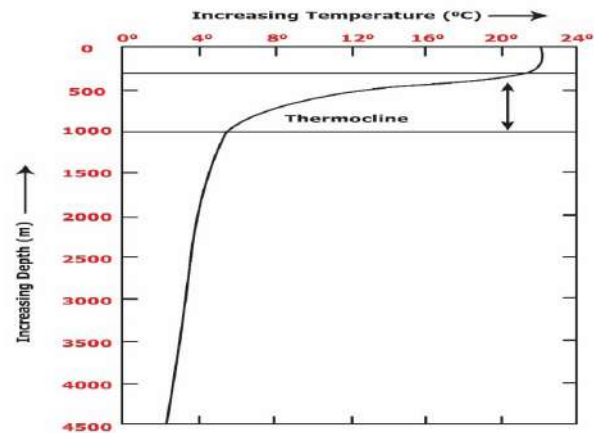


Fig. 13.3: Thermocline

- About **90 per cent of the total volume of water is found below the thermocline** in the deep ocean. In this zone, temperatures approach 0° C.
- The temperature structure of oceans over **middle and low latitudes** can be described as a **three-layer** system from surface to the bottom.
 - **The first layer:** It represents the **top layer** of warm oceanic water and it is about 500m thick with temperatures ranging between 20° and 25° C. This layer, within the tropical region, is present throughout the year but in mid latitudes it develops only during summer.
 - **The second layer:** It is called the **thermocline layer** lies below the first layer and is characterised by rapid decrease in temperature with increasing depth. The thermocline is 500 -1,000 m thick.

- **The third layer:** It is **very cold** and extends up to the deep ocean floor. In the Arctic and Antarctic circles, the surface water temperatures are close to 0° C and so the temperature change with the depth is very slight. Here, only one layer of cold water exists, which extends from surface to deep ocean floor.

Horizontal Distribution of Temperature:

- The average temperature of **surface water** of the oceans is about **27°C** and it **gradually decreases** from the **equator towards the poles**.
- The rate of decrease of temperature with increasing latitude is generally **0.5°C per latitude**.
- The average temperature is around 22°C at 20° latitudes, 14° C at 40° latitudes and 0° C near poles.
- The **oceans in the northern hemisphere record relatively higher temperature** than in the southern hemisphere.
- The **highest temperature is not recorded at the equator but slightly towards north of it**.
- The average annual temperatures for the northern and southern hemisphere are around **19° C and 16° C respectively**. This variation is due to the unequal distribution of land and water in the northern and southern hemispheres.
- The maximum temperature of the oceans is always at their **surfaces** because they directly receive the heat from the sun and the **heat is transmitted** to the lower sections of the oceans through the process of **convection**.

- The temperature falls very rapidly up to the depth of 200 m and thereafter, the rate of decrease of temperature is slowed down.

Salinity of Ocean Waters:

All waters in nature, whether rainwater or ocean water, contain dissolved mineral salts. **Salinity** is the term used to define the **total content of dissolved salts** in sea water.

- It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater.
- It is usually expressed **as parts per thousand (‰) or ppt**.
- Salinity is an important property of sea water.
- **Salinity of 24.7 ‰** has been considered as the upper limit to demarcate '**brackish water**'.

Factors affecting Ocean Salinity:

- The salinity of water in the surface layer of oceans depend mainly on **evaporation and precipitation**.
- Surface salinity is greatly influenced in coastal regions by the **fresh-water flow from rivers**, and in polar regions by the **processes of freezing and thawing of ice**.
- **Wind** also influences salinity of an area by transferring water to other areas.
- The **ocean currents** contribute to the salinity variations.
- Salinity, temperature and density of water are interrelated. Hence, any change in the temperature or density influences the salinity of water in an area.

Horizontal Distribution of Salinity:

- The salinity for normal open ocean ranges between 33 PPT and 37 PPT in the land locked **Red Sea**, it is as high as 41 PPT while in the estuaries and the Arctic, the salinity fluctuates from 0 - 35 PPT seasonally.
- In hot and dry regions, where evaporation is high, the **salinity sometimes reaches to 70 PPT**.
- The salinity variation in the **Pacific Ocean** is mainly due to its **shape** and larger areal extent.
- Salinity decreases from 35 PPT - 31 PPT on the western parts of the northern hemisphere because of the influx of melted water from the Arctic region. In the same way, after 15° - 20° south, it decreases to 33 PPT.
- The average salinity of the **Atlantic Ocean** is around 36 PPT. The highest salinity is recorded between 15° and 20° latitudes. Maximum salinity (37 PPT) is observed between 20° N and 30° N and 20° W - 60° W. It **gradually decreases towards the north**.
- **Baltic Sea** records **low salinity** due to influx of river waters in large quantity.
- **The Mediterranean Sea** records **higher salinity** due to high **evaporation**.
- Salinity is very **low in Black Sea** due to enormous fresh-water influx by rivers.
- The average salinity of the **Indian Ocean** is 35 PPT.
- The low salinity trend is observed in the **Bay of Bengal** due to influx of river water.

On the contrary, **the Arabian Sea** shows higher salinity due to high evaporation and low influx of fresh water.

Vertical Distribution of Salinity: Salinity changes with depth, but the way it changes depends upon the location of the sea.

- **Salinity at the surface increases** by the loss of water to ice or evaporation, or decreased by the input of fresh waters, such as from the rivers.
- Salinity at **depth** is very much **fixed** because there is no way that water is 'lost, or the salt is added.
- There is a marked difference in the salinity between the surface zones and the deep zones of the oceans.
- The **high salinity sea water sinks** below the lower salinity water this leads to stratification by salinity.
- **Salinity**, generally, **increases with depth** and there is a distinct zone called the **halocline**, where salinity increases sharply. Increasing salinity of seawater causes its density to increase.

Interesting Points:

- **Water Bodies with Highest Salinity:**
 - Lake Van in Turkey (330 ‰),
 - Dead Sea (238 ‰),
 - Great Salt Lake (220 ‰)
- The **earth** has an abundant supply of water on its surface. Hence, it is called the '**Blue Planet**'.



14

Movements of Ocean Water

The ocean water is dynamic. Its physical characteristics like temperature, salinity, density and the external forces like of the sun, moon and the winds influence the movement of ocean water.

Common Horizontal and Vertical Motions in Ocean Water Bodies:

- **The Horizontal motion:** It refers to the ocean **currents and waves**.
 - **Ocean currents:** These are the **continuous flow** of huge amount of water in a **definite direction**. Water moves ahead from one place to another through ocean currents.
 - **Waves:** These are the **horizontal motion** of water. The water in the waves does not move, but the wave trains move ahead.
- **The Vertical motion:** It refers to the **rise and fall** of water in the oceans and seas which is called tides.
 - Due to **attraction of the sun and the moon**, the ocean water is raised up and falls down **twice a day**.
 - The **upwelling** of cold water from subsurface and the **sinking** of surface water are also forming of vertical motion of ocean water.

Waves:

- Waves are **actually the energy, not the water** as such, which moves across the ocean surface.
- Water **particles only travel in a small circle** as a wave passes.
- **Wind provides energy** to the waves and **causes waves to travel** in the ocean and the energy is released on shorelines.
- The motion of the surface water **does not affect the stagnant deep bottom**

water of the oceans.

- As a wave approaches the beach, it slows down due to the friction occurring between the dynamic water and the sea floor.
- When the depth of water is less than half the wavelength of the wave, the wave breaks.
- The **largest waves** are found in the **open oceans**.
- Waves continue to grow larger as they move and absorb energy from the wind.
- Most of the waves are caused by the wind driving against water.
- When a breeze of two knots or less blows over calm water, small ripples form and grow as the wind speed increases until white caps appear in the breaking waves.
- Waves may travel thousands of km before rolling ashore, breaking and dissolving as surf.
- A **wave's size and shape** reveal its **origin**.
 - **Steep Waves:** They are **fairly young ones** and are probably formed by **local wind**.
 - **Slow and Steady Waves:** They originate from **faraway places**, possibly from another hemisphere.
- The maximum wave height is determined by the strength of the wind, i.e., how long it blows and the area over which it blows in a single direction.
- Waves travel because wind pushes the water body in its course while gravity pulls the crests of the waves downward. The falling water pushes the former troughs upward, and the wave moves to a new position.
- The **actual motion** of the **water beneath the waves** is **circular**. It indicates that

things are carried up and forward as the wave approaches, and down and back as it passes.

Characteristics of Waves:

- **Wave crest and trough:** The highest and lowest points of a wave are called the crest and trough, respectively.
- **Wave height:** It is the vertical distance from the bottom of a trough to the top of a crest of a wave.
- **Wave amplitude:** It is one-half of the wave height.
- **Wave period:** It is merely the time interval between two successive wave crests or troughs as they pass a fixed point.
- **Wavelength:** It is the horizontal distance between two successive crests.
- **Wave speed:** It is the rate at which the wave moves through the water and is measured in knots.
- **Wave frequency:** It is the number of waves passing a given point during a one second time interval.

Tides:

- The **periodical rise and fall** of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a **tide**.
- Movement of water caused by **meteorological effects** (winds and atmospheric pressure changes) are called **surges**. Surges are not regular like tides.

Factors responsible for Tides:

- **Gravitational pull:** The major causes for the occurrence of tides are the **moon's**

gravitational pull to a great extent and to a lesser extent the sun's gravitational pull.

- **Centrifugal force:** It is the force that acts to counterbalance the gravity.
- A **tidal bulge** occurs on the **side of the earth** facing the moon while on the opposite side though the gravitational attraction of the moon is less as it is farther away, the centrifugal force causes tidal bulge on the other side.

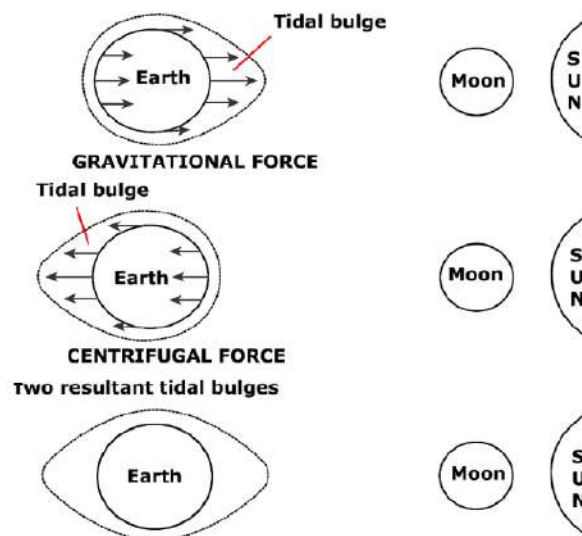


Fig. 14.1: Relation between gravitational forces and tides

- **'Tide-generating' force:** It is the **difference between these two forces**, i.e., the gravitational attraction of the moon and the centrifugal force.
- On the **surface of the earth**, nearest the moon, pull or the attractive force of the moon is greater than the centrifugal force, and so there is a **net force** causing a **bulge towards the moon**.
- On the **opposite side of the earth**, the **attractive force is** less, as it is farther

away from the moon, the centrifugal force is dominant. Hence, there is a **net force away from the moon**. It **creates the second bulge** away from the moon.

- On the surface of the earth, the horizontal tide generating forces are more important than the vertical forces in generating the tidal bulges.
- The tidal bulges on wide continental shelves, have greater height.
- When tidal bulges hit the mid-oceanic islands, they become low.
- The **shape of bays and estuaries** along a coastline can also **magnify the intensity of tides**. Funnel-shaped bays greatly change tidal magnitudes. When the tide is channelled between islands or into bays and estuaries, they are called **tidal currents**.

Types of Tides:

Tides vary in their frequency, direction and movement from place to place and also from time to time. Tides may be grouped into various types based on their frequency of occurrence in one day or 24 hours or based on their height.

Tide based on Frequency:

- **Semi-diurnal tide:** The most common tidal pattern, featuring **two high tides** and **two low tides each day**. The successive high or low tides are approximately of the same height.
- **Diurnal tide:** There is **only one high tide** and **one low tide** during **each day**. The successive high and low tides are approximately of the same height.
- **Mixed tide:** These are tides **having variations** in height. These tides generally occur along the west coast of

North America and on many islands of the Pacific Ocean.

Tides based on the Sun, Moon and the Earth Positions:

The height of rising water (high tide) varies appreciably depending upon the position of sun and moon with respect to the earth.

- **Spring tides:** The position of both the sun and the moon in relation to the earth has direct bearing on tide height.
 - When the **sun, the moon and the earth are in a straight line**, the height of the tide will be higher. These are called **spring tides**.
 - They **occur twice a month**, one on full moon period and another during new moon period.
- **Neap tides:** At this time, the **sun and moon are at right angles** to each other, and the forces of the sun and moon tend to counteract one another.
 - The Moon's attraction, though more than twice as strong as the sun's, is diminished by the counteracting force of the sun's gravitational pull.
 - Normally, there is a seven-day interval between the spring tides and neap tides.

Tidal Range:

- Once in a month, when the moon's orbit is closest to the earth (**perigee**), unusually high and low tides occur. During this time, the **tidal range is greater** than normal.
- Two weeks later, when the moon is farthest from earth (**apogee**), the moon's gravitational force is limited, and the **tidal ranges are less** than their average heights.

- When the Earth is closest to the Sun (**perihelion**), around 3rd January each year, tidal ranges are also much greater, with unusually high and unusually low tides.
- When the Earth is farthest from the Sun (**aphelion**), around 4th July each year, tidal ranges are much less than average.

Importance of Tides:

- The prediction of tides helps the **navigators and fishermen** plan their activities. Tidal flows are of great importance in navigation.
- Tidal heights are very important, especially harbours near rivers and within estuaries having shallow 'bars' at the entrance, which **prevent ships and boats from entering** into the harbour.
- They are helpful in **desilting the sediments** and in **removing polluted water** from river estuaries.
- Tides are used to **generate electrical power** (in Canada, France, Russia, and China). In India, a 3 MW tidal power project at Durgaduani in Sunderbans of West Bengal is under way.

Ocean Currents:

- Ocean currents are like **river flow in oceans**.
- They represent a regular volume of water in a definite path and direction.
- Ocean currents are influenced by two types of forces namely: **Primary forces** that **initiate** the **movement** of water and **Secondary forces** that **influence the currents** to flow.

Primary forces:

- **Heating by Solar energy:** It causes the **water to expand**. The ocean water is about 8 cm higher in level than in the middle latitudes near the equator. This causes a very **slight gradient** and water tends to flow down the slope.
- **Wind blowing:** On the surface of the ocean pushes the water to move. Friction between the wind and the water surface affects the movement of the water body in its course.
- **Gravity:** It tends to **pull the water down** the pile and create gradient variation.
- **Coriolis force:** It intervenes and causes the water to move to the **right** in the **northern hemisphere** and to the left in the southern hemisphere.
 - This results into accumulation of water at respective locations.
 - These large accumulations of water and the flow around them are called **Gyres**.
 - These produce large circular currents in all the ocean basins.

Secondary forces: Differences in water density affect **vertical mobility** of ocean currents.

- **Salinity:** Water with high salinity is denser than water with low salinity and in the same way cold water is denser than warm water. Differences in water density affect vertical mobility of ocean currents.
- **Temperature:** Denser water tends to sink, while relatively lighter water tends to rise.
 - **Cold-water** ocean currents occur when the cold water at the poles sinks and slowly moves towards the equator.

- **Warm-water** currents travel out from the equator along the surface, flowing towards the poles to replace the sinking cold water.

Characteristics of Ocean Currents:

- Usually, the **currents are strongest near the surface** and may attain speeds over five knots.
- At depths, currents are generally slow with speeds less than 0.5 knots. The speed of a current is referred as its “**drift.**” Drift is **measured in terms of knots.**
- The strength of a current refers to the speed of the current. A fast current is considered strong. A current is usually strongest at the surface and decreases in strength (speed) with depth.
- Most currents have speeds less than or equal to 5 knots.

Types of Ocean Currents

Classification based on their Depth:

- **Surface Currents:** It constitutes about **10 per cent of all the water** in the ocean and these waters are the upper 400 m of the ocean.
- **Deep water currents:** They make up the other 90 per cent of the ocean water.
 - These waters move around the ocean basins due to variations in the density and gravity.
 - Deep waters sink into the deep ocean basins at high latitudes, where the

temperatures are cold enough to cause the density to increase.

Classification based on Temperature:

- **Cold currents:** It **bring cold water** into warm water areas. These currents are usually found on the **west coast of the continents** in the low and middle latitudes (true in both hemispheres) and on the **east coast in the higher latitudes in the Northern Hemisphere.**
- **Warm currents:** These **bring warm water** into cold water areas and are usually observed on the **east coast of continents** in the low and middle latitudes (true in both hemispheres). In the **northern hemisphere they are found on the west coasts of continents in high latitudes.**

Major oceanic currents:

- Major ocean currents are greatly influenced by the stresses exerted by the prevailing winds and Coriolis force.
- The oceanic circulation pattern roughly corresponds to the earth’s atmospheric circulation pattern.
- The air circulation over the oceans in the middle latitudes is mainly **anticyclonic** (more pronounced in the southern hemisphere than in the northern hemisphere). The oceanic circulation pattern also corresponds with the same.

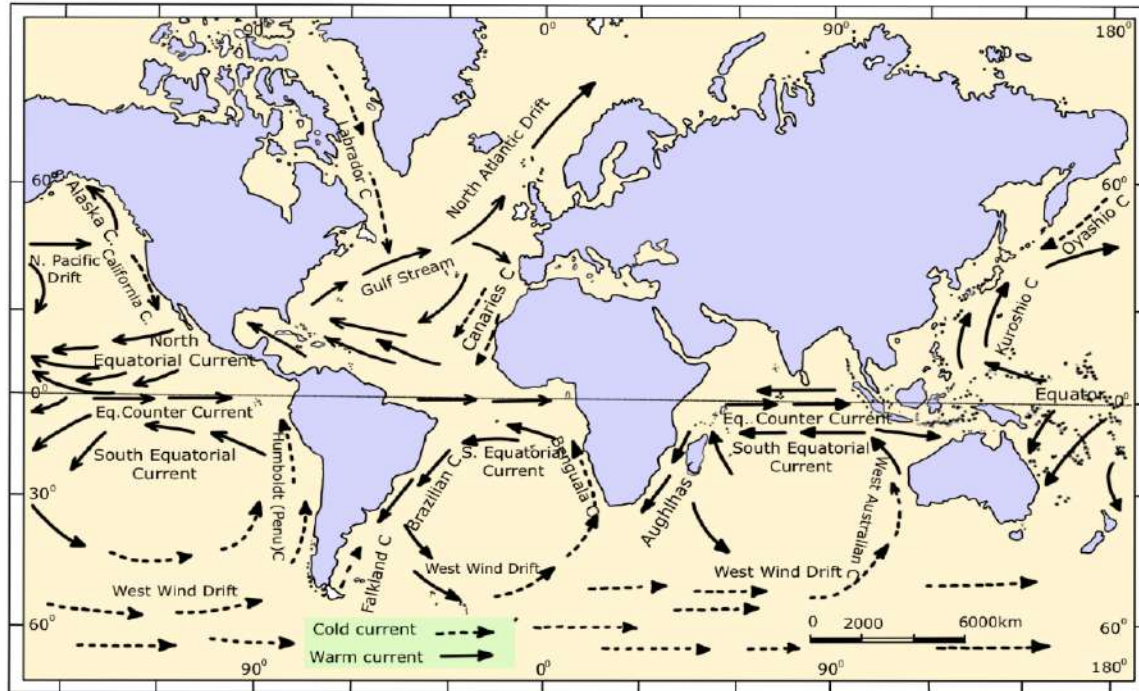


Fig. 14.2: Major currents in the Pacific, Atlantic and Indian oceans

- **At higher latitudes**, where the wind flow is mostly **cyclonic**, the oceanic circulation follows this pattern.
- In regions of pronounced monsoonal flow, the **monsoon winds** influence the current movements.
- The oceanic circulation transports heat from one latitude belt to another in a manner similar to the heat transported by the general circulation of the atmosphere.
- The cold waters of the Arctic and Antarctic circles move towards warmer water in tropical and equatorial regions, while the warm waters of the lower latitudes move pole wards.

Effects of Ocean Currents: Ocean currents have a number of direct and indirect influences on human activities.

- **West coasts** of the continents in **tropical and subtropical latitudes** (except close to the equator) are **bordered by cool waters**. Their average temperatures are relatively low with a narrow diurnal and annual ranges. There is fog, but generally the areas are arid.
- **West coasts** of the continents in the **middle and higher latitudes** are bordered by **warm waters** which cause a distinct marine climate. They are characterised by cool summers and relatively mild



winters with a narrow annual range of temperatures.

- **Warm currents flow parallel to the east coasts** of the continents in tropical and subtropical latitudes. This results in warm and rainy climates. These areas lie in the western margins of the subtropical anti-cyclones.
- The **mixing of warm and cold currents** helps to replenish the oxygen and favour the **growth of planktons**, the

primary food for fish population. The **best fishing grounds** of the world exist mainly in these mixing zones.

Interesting Points:

- **Ebb:** It is the time between the high tide and low tide, when the **water level is falling**.
- **Flow or flood:** It is the time between the low tide and high tide, when **the tide is rising**.



Unit VI: Life on the Earth



15

Life on the Earth

The **biosphere includes all the living organisms of the earth**. It consists of all plants and animals, including all the micro-organisms that live on the planet earth and their interactions with the surrounding environment. Most of the organisms exist on the lithosphere and/or the hydrosphere as well as in the atmosphere.

Ecology:

Ecology can be defined as a **scientific study of the interactions of organisms** with their physical environment and with each other.

- The **interactions** of a particular group of organisms with **abiotic factors** within a particular habitat resulting in clearly defined energy flows and material cycles on land, water and air, are called **ecological systems**.
- **Habitat:** In the ecological sense it is the **totality of the physical and chemical** factors that constitute the general environment.
- Different types of ecosystems exist with varying ranges of environmental conditions where various plants and animal species have got adapted through evolution. This phenomenon is known as **ecological adaptation**.
- The environment is made up of abiotic and biotic components. All these components in ecosystem are inter-related and interact with each other.

Types of Ecosystem: Ecosystems are of two major types namely terrestrial and aquatic.

Terrestrial ecosystem: It can be further classified into '**biomes**'.

- A biome is a **plant and animal community** that covers a **large geographical area**. The boundaries of different biomes on land are determined mainly by climate.
- A biome can be defined as the **total assemblage** of plant and animal species interacting within specific conditions. These include rainfall, temperature, humidity and soil conditions.
- Some of the major biomes of the world are forest, grassland, desert and tundra biomes.

Aquatic ecosystems: It can be classed as marine and freshwater ecosystems.

- **Marine ecosystem:** It includes the oceans, estuaries and coral reefs.
- **Freshwater ecosystem:** It includes lakes, ponds, streams, marshes and bogs.

Structure and Functions of the Ecosystem:

The structure of an ecosystem involves a description of the available plant and animal species. From a structural point of view, all ecosystems consist of abiotic and biotic factors.

- **Abiotic Factors:** They include rainfall, temperature, sunlight, atmospheric humidity, soil conditions, inorganic substances (carbon dioxide, water, nitrogen, calcium, phosphorus, potassium, etc.).
- **Biotic Factors:** It includes the producers, the consumers (primary, secondary, tertiary) and the decomposers.
 - **Producers:** It includes **all the green plants**, which manufacture their own food through **photosynthesis**.
 - **Primary consumers:** It include herbivorous animals like deer, goats, mice and all plant-eating animals.

The producers are consumed by the primary consumers.

- **Secondary consumers (carnivores):** It include all the flesh-eating animals like snakes, tigers and lions. The primary consumers are being eaten by the secondary consumers.
- **Tertiary consumers (Top Carnivores):** These are certain carnivores that feed on carnivores like hawks and mongooses.
- **Decomposers:** They are those that **feed on dead organisms** (for

example, **scavengers** like vultures and crows), and further breaking down of the dead matter by other decomposing agents like bacteria and various microorganism

- ◆ The decomposers feed on the dead at each and every level.
- ◆ They change them into various substances such as nutrients, organic and inorganic salts essential for soil fertility.

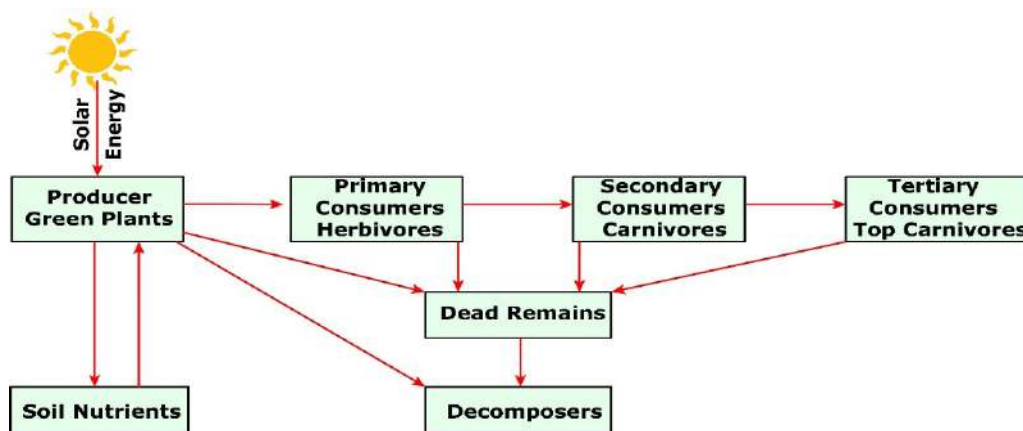


Fig. 15.1: Structure and functions of Ecosystems

Food Chain:

- Organisms of an ecosystem are **linked together** through a food chain. For example, a plant eating beetle feeding on a paddy stalk is eaten by a frog, which is, in turn, eaten by a snake, which is then consumed by a hawk.
- This **sequence of eating and being eaten** and the resultant **transfer of energy** from one level to another is known as the **food-chain**.

Flow of Energy: Transfer of energy that occurs during the process of a food-

chain from **one level to another** is known as **flow of energy**.

Food Web:

- Food-chains are not isolated from one another as there is interdependence of eating and being eaten between various organisms. For example, a mouse feeding on grain may be eaten by different secondary consumers (carnivores) and these carnivores may be eaten by other different tertiary consumers (top carnivores).

- In such situations, each of the carnivores may consume more than one type of prey. As a result, the food-chains get interlocked with one another. This **interconnecting network** of species is known as **food web**.
- Two types of food-chains are recognised namely grazing food-chain and detritus food-chain:

○ **Grazing Food-Chain:**

- ◆ In a grazing food-chain, the **first level starts with plants** as producers and ends with carnivores as consumers at the last level, with the herbivores being at the intermediate level.
- ◆ There is a loss of energy at each level which may be

through respiration, excretion or decomposition.

- ◆ The levels involved in a food-chain range between three to five and **energy is lost** at each level.

- **Detritus Food-Chain:** It is based on **autotrophs** energy capture **initiated** by grazing animals and involves the decomposition or breaking down of organic wastes and dead matter derived from the grazing food-chain.

Types of biomes:

There are five major biomes : forest, desert, grassland, aquatic and altitudinal biomes.

Table 15.1: World Biomes

Biomes	Subtypes	Regions	Climatic Characteristics	Soil	Flora and Fauna
Forest	A. Tropical 1. Equatorial 2. Deciduous B. Temperate C. Boreal	A1. 10° N S A2. 10°- 25° N-S B. Eastern North America, N.E. Asia, Western and Central Europe C. Broad belt of Eurasia and North America (parts of Siberia, Alaska, Canada and Scandinavia)	A1. Temp. 20-25°C, evenly distributed A2. Temp. 25-30°C, Rainfall, ave. ann, 1,000mm, seasonal B. Temp. 20-30° C, Rainfall evenly distributed 750 1,500mm, Well-defined seasons and distinct winter. C. Short moist moderately warm summers and long cold thy winter; very low temperatures. Precipitation mostly snowfall 400 -1,000mm	A1. Acidic, poor in nutrients A2. Rich in nutrients B. Fertile, en-riched with decaying litter C. Acidic and poor in nutrients, thin soil cover	A1. Multi-layered canopy tall and large trees A2. Less dense, trees of medium height: many varieties co-exist. Insects, bats, birds and mammals are common species in both B. Moderately dense broad leaved trees. With less diversity of plant species. Oak, Beach. Maple etc. are some common species. Squirrels, rabbits, skunks, birds, black bears, mountain lions etc. C. Evergreen conifers like pine. fur and spruce etc. Wood peckers. hawks, bears, wolves, deer, hares and bats are common animals
Desert	A. Hot and Dry desert B. Semi arid desert C. Coastal desert D. Cold desert	A. Sahara, Kalahari, Marusthali, Rub-el-Khali B. Marginal areas of hot deserts C. Atacama D. Tundra climatic regions	A. Temp. 20 - 45°C. B. 21 - 38°C. C. 15 - 35°C. D. 2 - 25°C A-D Rainfall is less than 50 mm	Rich in nutrients with little or no organic matter	A-C. Scanty vegetation: few large mammals, insects, reptiles and birds D. Rabbits, rats, antelopes and ground squirrels



Grassland	A. Tropical Savannah B. Temperate Steppe	A. Large areas of Africa, Australia, South America and India B. Parts of Eurasia and North America	A. Warm hot climates, Rainfall 500-1,250 mm B. Hot summers and cold winter. Rainfall 500 - 900 mm	A. Porous with thin layer of humus. B. Thin flocculated soil, rich in bases	A. Grasses; trees and large shrubs absent; giraffes, zebras, buffalos, leopards, hyenas, elephants, mice, moles, snakes and worms etc., are common animals B. Grasses; occasional trees such as cotton-woods, oaks and willows; gazelles, zebras, rhin-
-----------	---	---	--	--	--

					oceros, wild horses, lions, varieties of birds, worms, snakes etc., are common animals
Aquatic	A. Freshwater B. Marine	A. Lakes, streams, rivers and wetlands B. Oceans, coral reefs, lagoons and estuaries	A-B Temperatures vary widely with cooler air temperatures and high humidity	A. Water swamps and marshes B. Water, tidal swamps and marshes	Algal and other aquatic B. Marine and marshes plant communities with varieties of water dwelling animals
Altitudinal		Slopes of high mountain ranges like the Himalayas, the Andes and the Rockies	Temperature and precipitation vary depending upon latitudinal zone	Regolith over slopes	Deciduous to tundra vegetation varying according to altitude

Biogeochemical Cycles:

- The **sun** is the **basic source of energy** on which all life depends. This energy initiates life processes in the biosphere through photosynthesis, the main source of food and energy for green plants.
- During **photosynthesis**, **carbon dioxide** is **converted** into **organic compounds and oxygen**.
- Out of the total solar insolation that reaches the earth's surface, only a very small fraction (0.1 per cent) is fixed in photosynthesis. More than **half** of it is **used for plant respiration** and the remaining part is temporarily stored or is shifted to other portions of the plants.
- All living organisms exist and survive in a diversity of associations. Such survival involves the presence of systemic flows such as flows of energy, water and nutrients. These flows show variation in different part of the world in different seasons and various local factors.
- The balance between atmosphere and hydrosphere composed of same balance of chemical components. This balance of the chemical elements is maintained by a **cyclic passage** through the tissues of plants and animals.
- The **cycle starts** by **absorbing the chemical elements** by the **organism** and is returned to the air, water and soil through decomposition. These cycles are largely energised by solar insolation.
- These **cyclic movements of chemical elements** of the biosphere **between the organism and the environment** are referred to as **Biogeochemical cycles**.
- There are **two types** of biogeochemical cycles:

- **Gaseous Cycle:** The main reservoir of nutrients is the **atmosphere and the ocean**.
- **Sedimentary Cycle:** The main reservoir is the **soil and the sedimentary and other rocks** of the earth's crust.

The Water Cycle: All living organisms, the atmosphere and the lithosphere maintain between them a circulation of water in solid, liquid or gaseous form referred to as the **water or hydrologic cycle**.

The Carbon Cycle:

Carbon is one of the **basic elements of all living organisms**. It forms the

basic constituent of all the organic compounds.

- The carbon cycle is mainly the **conversion of carbon dioxide** which is initiated by the **fixation of carbon dioxide** from the atmosphere through photosynthesis.
- The conversion results in the production of **carbohydrate, glucose** that may be converted to other organic compounds such as sucrose, starch, cellulose, etc.
- Some of the carbohydrates are utilised directly by the plant itself. During this process, more **carbon dioxide is generated** and is released through its leaves or roots during the day.

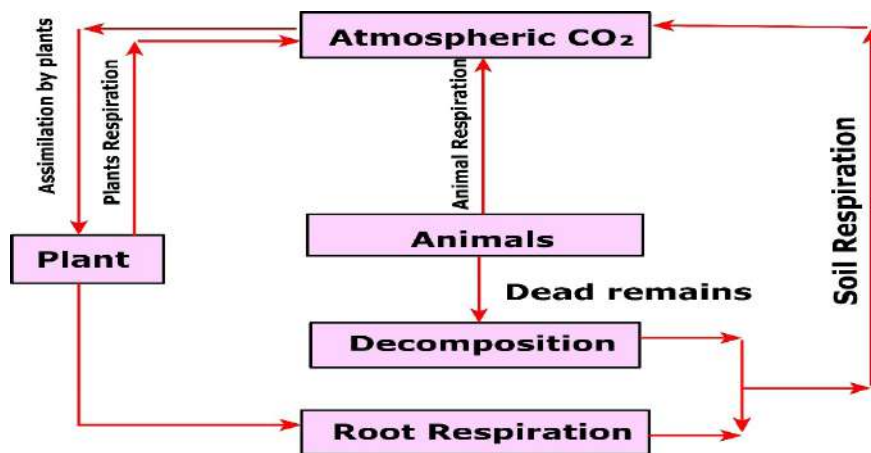


Fig. 15.2: Carbon Cycle

- The remaining carbohydrates not being utilised by the plant become part of the plant tissue which are being eaten by the herbivorous animals or get decomposed by the microorganisms.
- The **herbivores** convert some of the **consumed carbohydrates** into **carbon dioxide** for release into the air through **respiration**.
- The micro-organisms decompose the remaining carbohydrates after the animal dies. The carbohydrates that are decomposed by the micro-organisms then get **oxidised into carbon dioxide** and are returned to the atmosphere.

The Oxygen Cycle:

Oxygen is the **main by-product of photosynthesis**. It is involved in the oxidation of carbohydrates with the release of energy, carbon dioxide and water.

- The cycling of oxygen is a highly **complex process**.
- Oxygen occurs in a number of chemical forms and combinations. It combines with nitrogen to form nitrates and with many other minerals and elements to form various oxides such as the iron oxide, aluminium oxide and others.
- Much of oxygen is produced from the **decomposition of water molecules by sunlight during photosynthesis** and is released in the atmosphere through **transpiration and respiration** processes of plants.

The Nitrogen Cycle:

Nitrogen is a major constituent of the atmosphere comprising about **seventy-eight per cent** of the atmospheric gases. It is an essential constituent of different organic compounds such as the amino acids, nucleic acids, proteins, vitamins and pigments.

- Only a few types of organisms like certain species of **soil bacteria and blue green algae** can utilise it **directly in its gaseous form**.
- Nitrogen is **usable** only **after it is fixed**. **Ninety per cent of fixed nitrogen is biological**.
- The principal source of free nitrogen is the action of soil micro-organisms and associated plant roots on atmospheric nitrogen found in pore spaces of the soil.

- Nitrogen can also be fixed in the **atmosphere** by **lightning and cosmic radiation**.
- In the oceans, some marine animals can fix it.
- After atmospheric nitrogen has been fixed into an available form, **green plants can assimilate** it.
- Herbivorous animals feeding on plants, in turn, consume some of it.
- Dead plants and animals, excretion of nitrogenous wastes is converted into **nitrites** by the **action of bacteria** present in the soil.
- Some bacteria can even convert **nitrites into nitrates** that can be used again by green plants.
- There are still other types of bacteria capable of converting **nitrates into free nitrogen**, a process known as **denitrification**.

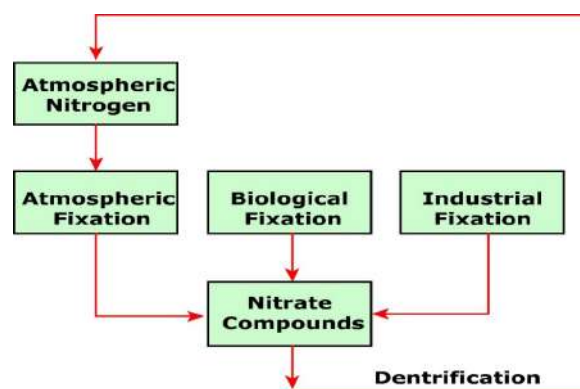


Fig. 15.3: Nitrogen Cycle

Other Mineral Cycles:

Certain minerals critical nutrients for plant and animal life. They are obtained from **inorganic sources** such as Phosphorus, Sulphur, Calcium and Potassium.

- They usually occur as **salts dissolved** in soil water or lakes, streams and seas.
- **Mineral salts** come **directly from the earth's crust** by weathering where the soluble salts enter the water cycle, eventually reaching the sea.
- Other salts are returned to the earth's surface through **sedimentation**, and after **weathering**, they again enter the cycle.
- All living organisms fulfil their mineral requirements from mineral solutions in their environments and some animals also receive their mineral needs from their **consumption** of plants and animals.
- After the death of living organisms, the minerals are returned to the soil and water through **decomposition** and flow.

Ecological Balance:

- Ecological balance is a **state of dynamic equilibrium** within a community of organisms in a habitat or ecosystem.
- It can happen when the **diversity** of the living organisms **remains relatively stable**.
- Gradual changes do take place but that happens only through **natural succession**.
- It can also be explained as a stable balance in the numbers of each species in an ecosystem. This occurs through **competition and cooperation** between different organisms where population remains stable.
- This balance is also attained by the fact that some species depend on others for their food and sustenance.

- Such accounts are encountered in vast grasslands where the herbivorous animals (deer, zebras, buffaloes, etc.) are found in plenty.
- On the other hand, the carnivorous animals (tigers, lions, etc.) that are not usually in large numbers, hunt and feed on the herbivores, thereby controlling their population.
- In the plants, any disturbance in the native forests such as clearing the forest for shifting cultivation usually brings about a change in the species distribution. This change is due to competition where the **secondary forest** species such as grasses, bamboos or pines **overtakes the native species** changing the original forest structure. This is called **succession**.

Disturbance to Ecological Balance:

- Ecological balance may be disturbed due to the **introduction of new species, natural hazards or human causes**.
- **Human interference** has affected the balance of plant communities leading to disturbances in the ecosystems. Such disturbances bring about **numerous secondary successions**.
- Human pressure on the earth's resources has put a heavy toll on the ecosystem. This has destroyed its originality and has caused adverse effects to the general environment.
- Ecological imbalances have brought **many natural calamities** like floods, landslides, diseases, erratic climatic occurrences, etc.

-
- There is a very close relationship between the plant and animal communities within particular habitats.
 - Diversity of life in a particular area can be employed as an indicator of the habitat factor.

Interesting Points:

- A German zoologist **Ernst Haeckel**, who used the term as 'oikology' in **1869**,

became the first person to use the term '**ecology**'.

- The study of interactions between life forms (biotic) and the physical environment (abiotic) is the **science of ecology**.



16

Biodiversity and Conservation

Weathered material of the earth provides base for diversity of vegetation and vegetation provides essential base for survival of the biodiversity. The basic cause for such weathering variations and resultant biodiversity is the input of solar energy and water.

Biodiversity:

- Biodiversity is the **number and variety** of **organisms** found within a specified geographic region. It refers to the varieties of plants, animals and micro-organisms, their genes etc.
- Biodiversity is a **system in constant evolution**, from a viewpoint of species and an individual organism.
- It relates to the variability among living organisms on the earth, including the variability within and between the species and that within and between the ecosystems.
- The **average half-life of a species** is estimated between one and four million years, and 99 per cent of the species that have ever lived on the earth are today extinct.
- Biodiversity is not found evenly on the earth. It is consistently **richer in the tropics** and as one approaches the polar regions, one finds larger and larger populations of fewer and fewer species.

Levels of Biodiversity**Genetic Diversity:**

- Genes are the **basic building blocks** of various life forms.
- Genetic biodiversity refers to the **variation of genes within species**.

- Groups of individual organisms having certain **similarities in their physical characteristics** are called **species**.
- Human beings genetically belong to the **homo sapiens group** and also differ in their characteristics such as height, colour, physical appearance, etc. This is due to genetic diversity.
- The genetic diversity is **essential for a healthy breeding** of population of species.

Species Diversity:

- Species Diversity refers to the variety of species and relates to the **number of species in a defined area**.
- The diversity of species can be measured through its richness, abundance and types.
- Some areas are richer in species than others.
- Areas **rich in species diversity** are called '**hotspots of diversity**'.

Ecosystem Diversity:

- The broad **differences** between **ecosystem types and the diversity** of habitats and ecological processes occurring within each ecosystem type constitute the **ecosystem diversity**.
- The 'boundaries' of communities (associations of species) and ecosystems are not very rigidly defined. Thus, the demarcation of ecosystem boundaries is difficult and complex.

Importance of Biodiversity: Biodiversity has contributed in many ways to the development of human culture, and, in turn, human communities have played

a major role in shaping the diversity of nature at the genetic, species and ecological levels. Biodiversity plays the following roles:

Ecological Role of Biodiversity:

- Various species perform various functions at various level in ecosystem. Nothing in an ecosystem evolves and sustains without any reason.
- **Functions** like species capture and store energy, produce and decompose organic materials, help to **cycle water and nutrients** throughout the ecosystem, **fix atmospheric gases** and help **regulate the climate**.
- These functions are important for ecosystem function and human survival.
- The **more diverse** ecosystem has better chances for the species to survive through adversities and attacks, and consequently, is more **productive**.
- Hence, the loss of species would decrease the ability of the system to maintain itself.
- Just like a species with a high genetic diversity, an **ecosystem with high biodiversity may have a greater chance of adapting** to environmental change.

Economic Role of Biodiversity:

- One important part of biodiversity is '**crop diversity**', which is also called **Agro-Biodiversity**.
- Biodiversity is seen as a **reservoir of resources** to be drawn upon for the manufacture of food, pharmaceutical, and cosmetic products.
- Some of the important economic commodities that biodiversity supplies

to humankind are food crops, livestock, forests, fish, medicinal resources, etc.

Scientific Role of Biodiversity:

- Biodiversity is important because each species give some **clue about evolution of life**.
- Biodiversity also helps in **understanding functioning of life** and the **role of each species** in sustaining ecosystems.

Loss of Biodiversity:

- The growth in human population has increased the rate of consumption of natural resources. It has accelerated the loss of species and habitation in different parts of the world.
- **Tropical regions** which occupy only about **one-fourth of the total area** of the world, contain about **three fourth** of the world human population.
 - **Overexploitation of resources** and **deforestation** have become rampant to fulfil the needs of large population.
 - As these **tropical rain forests contain 50 per cent of the species** on the earth, destruction of natural habitats has proved disastrous for the entire biosphere.
- **Natural calamities** such as earthquakes, floods, volcanic eruptions, forest fires, droughts, etc. cause damage to the flora and fauna of the earth, bringing change the biodiversity of respective affected regions.
- **Pesticides and other pollutants** such as hydrocarbons and toxic heavy metals destroy the weak and sensitive species.

- **Species** which are **not the natural inhabitants** of the local habitat but are introduced into the system, are called **exotic species**.
- During the last few decades, some animals like tigers, elephants, rhinoceros, crocodiles, minks and birds were **hunted mercilessly by poachers** for their horn, tusks, hides, etc.

Classification of Threatened Species:

The **International Union of Conservation of Nature and Natural Resources (IUCN)** has classified the threatened species of plants and animals into three categories **for the purpose of their conservation**.

Endangered Species:

- It includes those **species** which are in **danger of extinction**.
- The IUCN publishes information about endangered species world-wide as the **Red List of threatened species**.

Vulnerable Species:

- This includes the species which are **likely** to be in **danger of extinction in near future** if the factors threatening to their extinction continue.
- Survival of these species is not assured as their population has reduced greatly.

Rare Species:

- Population of these species is very small in the world and they are **confined to limited areas** or **thinly scattered over a wider area**.

Conservation of Biodiversity:

- All forms of life are so closely interlinked that disturbance in one

give rise to imbalance in the others. If species of plants and animals become endangered, they cause degradation in the environment, which may threaten human being's own existence.

- There is an urgent need to educate people to adopt **environment-friendly practices** and reorient their activities in such a way that our development is harmonious with other life forms and is sustainable.
- There is an increasing consciousness of the fact that conservation with sustainable use is possible only with the involvement and cooperation of **local communities and individuals**. For this the development of **institutional structures at local levels** is necessary.

The Earth Summit (1992):

The Government of India along with 155 other nations have signed the **Convention of Biodiversity at the Earth Summit** held at Rio de Janeiro, Brazil in June 1992. The world conservation strategy has suggested the following steps for biodiversity conservation:

- Efforts should be made to **preserve the species that are endangered**.
- Prevention of extinction requires proper **planning and management**.
- **Varieties** of food crops, forage plants, timber trees, livestock, animals and **their wild relatives** should be **preserved**.
- Each country should **identify habitats of wild relatives** and ensure their protection.
- Habitats where species feed, breed, rest and nurse their **young should be safeguarded and protected**.

- **International trade** in wild plants and animals be **regulated**.

Conservation of Biodiversity steps by India: To protect, preserve and propagate the variety of species within natural boundaries, the Government of India passed the **Wildlife (Protection) Act, 1972**, under which **national parks and sanctuaries** were established and **biosphere reserves declared**.

Mega Diversity Centres:

- There are some countries which are situated in the tropical region and possess a large number of the world's species diversity. They are called **mega diversity centres**.
- There are **12 such countries**, namely Mexico, Columbia, Ecuador, Peru,

Brazil, Democratic Republic of Congo, Madagascar, China, **India**, Malaysia, Indonesia and Australia in which these centres are located.

Biodiversity Hotspots:

- The **IUCN** has identified certain areas as biodiversity hotspots in order to concentrate resources on those areas that are most vulnerable.
- Hotspots are defined according to their vegetation. Plants are important because these determine the primary productivity of an ecosystem. Most, but not all, of the **hotspots rely on species-rich ecosystems** for food, firewood, cropland, and income from timber.

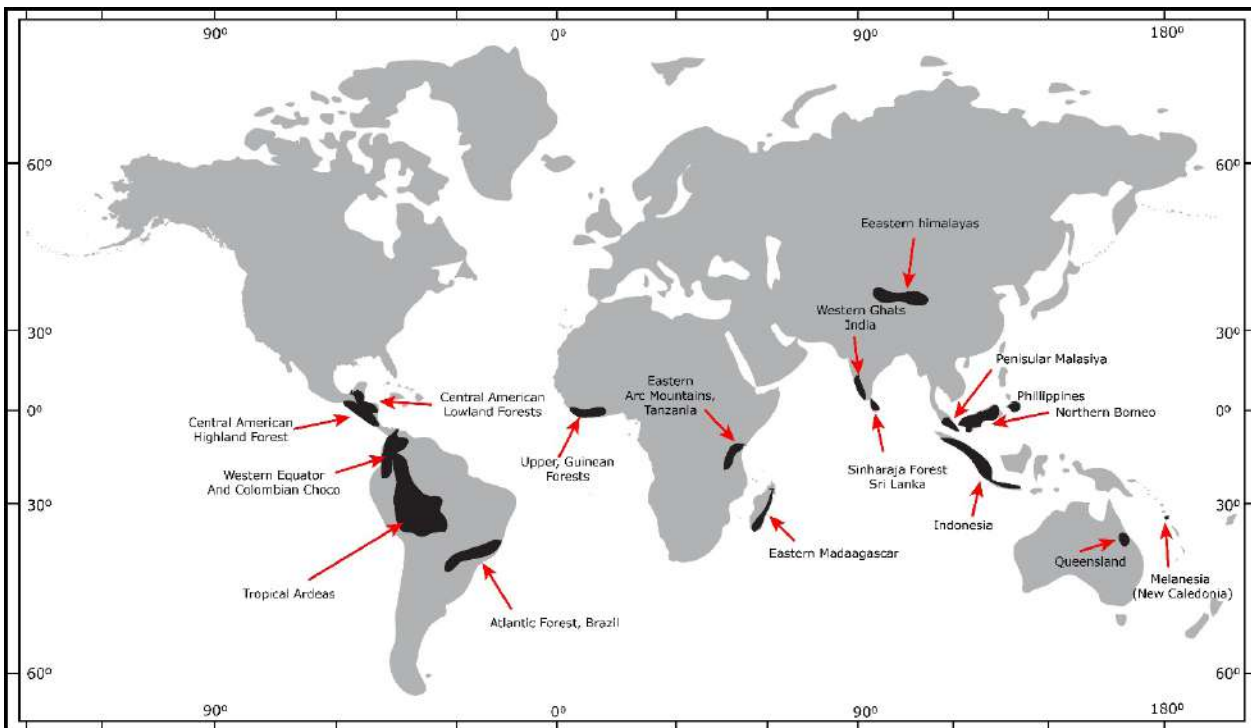


Fig. 16.1: Some Ecological 'hotspots' in the world



Interesting Points:

- **Biodiversity** today is the result of **2.5-3.5 billion years of evolution**. Since, the emergence of humans, however, biodiversity has begun a rapid decline, with one species after another bearing the brunt of extinction due to overuse.
- The **number of species** globally vary from 2 million to 100 million, with **10 million** being the best estimate.
- New species are regularly discovered most of which are yet to be classified. An estimate states that about **40 per cent of freshwater fishes from South America are not classified yet**.
- The **islands of Hawaii** have many unique plants and animals that are threatened by introduced species and land development.